IMPACT OF DECISION CRITERIA ON FEDERAL AVIATION ADMINISTRATION CERTIFICATION OF MILITARY COMMERCIAL DERIVATIVE AIRCRAFT

THESIS

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IMPACT OF DECISION CRITERIA ON FEDERAL AVIATION ADMINISTRATION

CERTIFICATION OF MILITARY COMMERCIAL DERIVATIVE AIRCRAFT

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Abstract

The decision regarding whether to maintain Federal Aviation Administration certification of military commercial derivative aircraft (MCDA) can be extremely difficult due to the subjective nature of some of the associated costs and benefits. The purpose of this research is to help decision makers understand the level of impact those costs and benefits have on their decision and how that impact may change over the lifecycle of the MCDA fleet. Data regarding the various criteria involved in such decisions were collected from subject matter experts using the Delphi technique. This information was then incorporated into a decision support tool that uses the principles of multi-attribute decision making. The tool helps to illustrate the relative importance of each of the decision criteria based upon specific points in a typical MCDA fleet lifecycle.

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I. Introduction

Overview

This thesis helps identify criteria that U.S. Air Force (USAF) leaders and decision makers can use determine whether maintaining Federal Aviation Administration (FAA) certification of military commercial derivative aircraft (MCDA) is beneficial when compared to maintaining only military certification. This chapter helps to lay the groundwork for understanding what FAA and military certifications are and how they apply to MCDA. First, background on FAA and military certification is provided, followed by current problems and concerns Air Force leaders are facing regarding MCDA certification. Next, the focus of the research behind these issues is presented, as well as an outline of the primary research objectives. Finally, assumptions and limitations to the research are identified, along with how they might impact findings and conclusions.

Background

Over the last century, the field of U.S. aviation has grown from a relatively small industry with only a few aircraft used primarily for observation and mail delivery, into a thriving commercial and military industry that employs literally thousands of aircraft that play vital roles in our national defense. At an early stage of this industry's growth, it was

imperative that some form of regulation be implemented in the areas of aircraft production, maintenance, and operations in order to ensure that fundamental levels of quality, safety, and consistency were achieved. An industry as large as aviation typically needs some form of regulation or a set of standardized practices that can be agreed to and then enforced by a central body or government agency (“A Brief History,” 2011). With the right level of regulatory oversight, a strong foundation of quality and safety become just as important to an organization’s success as profits or capabilities. Most military and civilian leaders alike would agree that there is value in following a well-documented practice of certifying the quality and airworthiness of aircraft as well as adhering to firmly established and consistent maintenance practices.

Established early-on in the aviation industry, the aircraft and maintenance certification process has evolved into something very complex and specialized. Whether used to certify aircraft airworthiness, maintenance procedures, or maintenance personnel, achieving certification (FAA or otherwise) often requires following a set of complicated and circuitous steps that can sometimes take a great deal of time and technical knowledge to navigate. Adding to this complexity are the many types of certifications and certification waivers, as well as the implications that the requirements of each brings about over the lifecycle of the aircraft or process being certified. In any case, deciding which option is best (or most cost effective) for an organization can be extremely challenging, and is certainly a decision that should never be made without a thorough understanding of all possibilities. To be sure, this is an area in which leadership decisions have a serious impact on operational budgets, not to mention the impact they have on organizational quality and safety levels.

Additional consideration must also be given to the rate at which the certification process changes in relation to the rest of the industry. For example, not only do our decision makers and program managers need to decide whether or not military airworthiness certification is sufficient for the aircraft they manage, but they must also be able to determine if the certification process itself is adequate. In other words, while we struggle with the decision over which type of certification to pursue, the reality is that the certification process itself, in a very broad sense, may in fact be outdated and hindering the technical growth of the industry. This is an important area of discussion that goes beyond the scope of this paper, but was identified as a potential area for future research.

Problem Statement

Considering that the military and civilian aviation industries do not necessarily take the same paths regarding requirements and regulations, it is possible that some confusion may exist with regard to USAF and FAA policies. Examples of differences may include the types of forms used to track aircraft parts or the FAA's use of Airworthiness Directives to pass along safety alert messages (FAA FAQ, 2011). This is not to say that both organizations are not equally concerned with mission accomplishment, only that sometimes the primary focus of the FAA is safety, while the primary focus of military organizations is operational effectiveness (Bongiovi, Rob, Darrell Holcomb, Milt Ross, Bill Stockman, & Tony Perfilio, 2009). Overlapping areas or gaps in policy can become grey areas where interpretations may vary, and this can make it difficult for industry and military decision makers to make fact-based decisions. Instead, decisions might be made based on current interpretation, which can be biased by

factors such as current budget constraints or manpower levels. In the worst case, the resulting decision may not be optimal because it was based on incomplete information.

As this problem relates to the decisions being made regarding aircraft certification, current acquisition and sustainment decision criteria are typically not standardized in a way that assists leaders in determining whether or not, from a life cycle management perspective, USAF aircraft should be managed as FAA certified commercial derivatives. Such determinations would include consideration of the various FAA certifications of aircraft, repair stations, and personnel. One of the difficult decisions facing our program managers today is whether or not pushing aircraft and supporting processes to follow FAA certification requirements is cost effective (Stockman, William, Milt Ross, Robert Bongiovi, & Greg Sparks, 2011). Before any of those questions can be answered accurately, there must first be a very firm and clear understanding of exactly what the benefits of maintaining certification might be, as well as associated costs, and the origins of both. To help clarify these areas, the researcher uses the Delphi method with subject matter experts (SME) having leadership and decision making experience in fields pertaining to USAF aircraft acquisition and sustainment. The goal of the study is to reach a consensus of opinion regarding the various risks and benefits associated with utilization of MCDA and subsequent FAA certification of those aircraft. The Delphi method is discussed in greater detail in the methodology section of this paper. Additionally, results of the Delphi study were used to develop a simple decision support tool that utilizes some of the aspects of Multiple Attribute Decision Making (MADM). The support tool and MADM attributes are also discussed in later chapters.

Research Focus

The research will focus on trying to clearly identify the benefits associated with maintaining FAA certification, and how those benefits can change over the life cycle of an aircraft fleet. This is not a simple question of financial costs, as many of the potential benefits are fairly subjective and ambiguous. In that regard, some subjective weighting of each benefit will have to be made because, while FAA aircraft certification is similar to its military counterpart, it can be difficult to make detailed comparisons between the two. This is not to say that there is a great deal of difference between the quality levels or thoroughness of repair occurring within the military and commercial aviation industry, but simply that there are some differences in policy and administration.

As with any large-scale process of this type, there will almost certainly never be a one-size-fits-all decision tool that will determine conclusively if maintaining FAA certification is right for every aircraft type. In fact, it is likely that there are several criteria that must be analyzed for each individual decision, and results will be subjective. However, with a more thorough understanding of these criteria, decision makers should be able to more accurately determine if the potential benefits outweigh the costs associated with the certifications required within their specific areas.

Research Objectives

The objective of this research will be to help identify clear and understandable (though sometimes very general) criteria for determining if maintaining FAA certification on MCDA currently in use (or being considered for future use) is warranted based on potential benefits or efficiencies achieved by it. In other words, it is the goal of this research to provide decision makers some additional tools to help them determine if

maintaining an ongoing partnership with the FAA is in their best interest, and if so, for how long. As discussed later in this paper, maintaining FAA certification is not necessarily an all-or-nothing prospect. In fact, there are many decision variables associated with milestones that occur during an aircraft life cycle that may actually lead to a decision to only maintain FAA certification for a relatively short period of time. As mentioned earlier, the final decision will likely be based on some fairly subjective and situation-specific measures.

In an effort to produce a tool or model generic enough to have far reaching applicability while still maintaining validity, several underlying factors had to be considered, such as spare parts availability, type of maintenance support, and participation in a common parts pool. Also, many of these factors must be adjusted based on whether the solution chosen involves temporary FAA certification or certification over the entire life cycle of the system.

Summary

It can be difficult for decision makers to fully understand the impact of all aspects of FAA certification, and just as difficult to determine if maintaining that certification is the right course of action. This chapter outlined some of the problems faced while making that decision as well as how the focus of this research is aimed at clarifying the decision criteria. Chapter Two will provide background on the certification process itself, as well as outline some of the potential costs and benefits associated with maintaining FAA certification. The research methodology is then described in Chapter Three. Specifically, the use of the Delphi technique and multi-attribute decision making principles are explained with regard to the gathering of data and decision support tool

construction. Results of these methods are outlined in Chapter Four, with conclusions and recommendations provided in Chapter Five.

II. Literature Review

Overview

Supporting inputs used in the decisions regarding the use and duration of FAA certification of MCDA come from many levels. The professional backgrounds of personnel involved in these decisions can vary greatly, so it is important for all decision makers, regardless of level, to have a thorough understanding of the costs and benefits associated with USAF use of commercial derivatives, as well as the various military and FAA certifications required. A common understanding of the benefits associated with FAA certification must also be achieved.

Due to the wide range of knowledge and experience of the personnel involved in the decision making, this chapter begins with a brief background of MCDA, the reasons behind aircraft certification, as well as the various types of certification. Next, a discussion of some of the primary benefits associated with maintaining FAA certification is provided as a means of establishing a common understanding in this area. The method behind identifying some of these benefits was the Delphi technique, which will be discussed later in the chapter. Finally, the chapter concludes with an analysis of MADM principles and how they were used to prioritize the benefits and show how those benefits might change over the life cycle of an aircraft.

Military Commercial Derivative Aircraft (MCDA)

At a very basic level, a military commercial derivative aircraft is based upon an existing or planned commercial design, but has typically been modified from its original configuration. As defined by AFI 62-601, *USAF Airworthiness* (11 June 2010), a MCDA is “any fixed- or rotary-wing aircraft procured as a commercial, FAA type certified, off-the-

shelf non-developmental item, and whose serial number is listed on an FAA Type Certificate Data Sheet." Nearly all military aircraft have some level commercial variation, which can range from minor parts or components to complete aircraft systems. In fact, a report released from the Defense Science Board in 2009 outlined eight levels of commercial systems that are used by the military, as shown in Table 1.

Table 1: Levels of Commercial Systems ("Buying Commercial," 2009)

Level	Definitions of "Commercial Systems"
1	Buy it from a manufacturer—domestic or foreign—and use it as is
2	Buy it from a manufacturer and make minor modifications; i.e., "paint it green"
3	Buy it from a manufacturer and make significant modifications, i.e., adding armored doors, guns, military radio, or a ballistically-tolerant fuel system
4	Have a manufacturer make significant modifications before buying it
5	Have a manufacturer gut an existing product and replace most of it with other (military-specified) parts
6	Have a manufacturer modify a commercial prototype product to meet military requirements
7	Have a manufacturer assemble a collection of commercial and military components independently qualified on different systems
8	A product that does not yet exist, but requires commercial development and utilizes commercial plants or processes

Some of the benefits associated with military use of commercial derivatives diminish as the level number outlined in Table 1 increases. For example, Levels 1 and 2 represent military use of commercial-off-the-shelf (COTS) systems (with only minor modification), and as such, development and production costs would likely be spread over a large pool of customers, significantly reducing costs to the USAF ("Buying Commercial," 2009). One factor that helps to determine the amount of cost savings achieved in such a situation is the point of the production run at which the aircraft is

purchased, and this will be discussed in greater detail in Chapter Three. There are potentially many other cost saving opportunities such as taking advantage of existing FAA testing and certification. Additional sustainment related items such as utilization of existing infrastructure, facilities, resources, and best practices, which will also be discussed in later sections, can be leveraged as well. However, as program managers consider using commercial derivatives, they must keep in mind that the costs associated with even minor modifications are high, and can quickly overtake the initial savings achieved by utilizing COTS systems ("Buying Commercial," 2009). One way to avoid this is to ensure that military requirements closely match commercial derivative design. If they do not, then program managers may be considering factors in the higher levels of Table 1, and perhaps commercial derivatives would not be the right course of action. Other costs that are often overlooked are those associated with complying with Federal Acquisition Regulations (FAR). These regulations are the specific sets of rules that govern the federal acquisition process (Acquisition Central, 2012). For example, for complex purchases such as those discussed here, FAR requirements can add substantial costs to the process in the form of regulation compliance and oversight, and in fact, can make government contracts unappealing to potentially competing firms. Smaller contractors that do not have experience dealing with government contracts can quickly become overburdened by FAR requirements (Edwards, 2003).

The Origin of Aircraft Certification

The idea of aircraft certification has its roots in the subsidization of commercial airmail routes in 1925 with the passage of the Kelly Airmail Act. Privatization of airmail delivery furthered the growth of the private aviation business and highlighted the need to

establish regulations that would standardize aviation practices and procedures. Additional pressure to enact this type of regulation came from General William “Billy” Mitchell, who was a proponent of an independent air force and pressured the U.S. President at the time, Calvin Coolidge, to pass new aviation legislation. To that effort, President Coolidge established a board to determine the status of aviation in the U.S., and chose Dwight Morrow, a Wall Street Banker, to lead it. This board came to be known as the Morrow Board, and their initial recommendations included establishing a Bureau of Air Navigation in order to address the overall lack of aviation infrastructure in the U.S., (since the U.S. was lagging Europe in this area), as well as establishing the Department of National Defense. Additionally, the board made recommendations regarding standardizing procedures, which further supported the need for government legislation of the aviation industry. Based on the results of the Morrow Board, President Coolidge eventually signed into law the Air Commerce Act of 1926 (Downs, 2001).

The Air Commerce Act charged the Secretary of Commerce with, among many other things, enforcing air traffic rules, licensing pilots, and certifying aircraft. Several years later, the establishment of the Bureau of Air Commerce in 1934 and the Civil Aeronautics Authority in 1938 eventually culminated into the creation of the Federal Aviation Agency with the Federal Aviation Act of 1958. These continuing changes to the legislation and those enforcing it were required due to the quickly expanding nature of the industry. The name change from the Federal Aviation Agency to the Federal Aviation Administration (as it is known today) was the result of the establishment of the Department of Transportation under the Johnson administration, which encompassed the new Federal Aviation Administration (Federal Aviation, 2010).

These newly emerging agencies and regulations became ever more important as WWII began and the government looked to a fairly young aviation industry as the source for thousands of safe and reliable aircraft to support the war effort, as well as a source for the extensive supply chains necessary to support them. Until then, post WWI military aircraft that had flooded the commercial market had not been maintained consistently, and most flying organizations depended on the original equipment manufacturer (OEM) or organic maintenance for repair actions. However, as early aircraft were not initially designed (or expected) to last a long time, they were actually considered somewhat disposable, sometimes only used for a decade or less before being replaced by new designs. Leading up to and during WWII, most aircraft repairs were accomplished locally, and those aircraft that were not repairable were cannibalized for spare parts. This was generally the case regardless of whether the aircraft were for military or commercial use (Stockman et al., 2011).

In 1944, near the end of WWII, the U.S. invited its allies to meet and share ideas regarding the future of international civil aviation. This meeting, held in Chicago, ultimately led to the creation of the International Civil Aviation Organization (ICAO) as well as the development of the concept of a standard certification of aircraft airworthiness. It was believed that regulating the aviation industry and establishing airworthiness certification requirements would help ensure aircraft would be produced in accordance with approved designs and that manufacturers and operators would perform the required level of maintenance and alterations in accordance with standard policy (ICAO, 1944: Annex 8).

Following WWII, special demands for military transport required aircraft with very large and spacious interiors that were easy to load and unload, with the additional capability of landing and taking off on dirt landing strips. Because of these special requirements, the military developed unique aircraft that were specific to their missions. Aircraft such as the C-130, C-141, and others were produced that were not designed for use in commercial markets. These unique aircraft required their own military-specific maintenance infrastructure, to include organic maintainers and depot facilities (Feltus, 2010). These types of separate military requirements, coupled with the manufacture of specific aircraft to meet them contributed to the Air Force's eventual decision to develop their own airworthiness certification process independent from the FAA. Although in some cases, USAF aircraft had already received prior FAA certification (Humerick & Minnich, 1992)

MCDA Certification Basics

The FAA Military Certification Office (MCO) is the point of contact for the armed services with regard to MCDA certification, providing technical support, certification, and airworthiness services for MCDA (U.S. DOT Type Certification, 2007). The MCO also assists with establishing unique policies and procedures that address the challenges surrounding FAA support of military applications. The extent of these services provided by the FAA is further outlined in a Memorandum of Agreement (MOA) between the FAA and the military services, signed in 2007. The MOA provides details regarding the scope of support the FAA will provide for MCDA activities, as well as reporting requirements and approval authorities. Under this MOA, the FAA had also certificated military-only repair stations that performed maintenance and inspection of

parts and components being used solely by the military (also known as Part 145 certification, in reference to the part of the FAA regulation covering repair station certification requirements) (FAA Interagency MOA, 2007). However, a review of the MOA that was conducted in 2009 determined that the term "technical assistance" contained in the MOA did not provide for Part 145 certification of military repair stations. As such, a follow on memo signed in 2010 stated that the FAA would no longer issue such certificates to Department of Defense (DOD) entities performing work solely on U.S. military products (FAA Memorandum, 2010).

Types of Certification

FAA Certifications

The certifications that the FAA normally provides for typical commercial aircraft include Type Certificates, Airworthiness Certificates, and Production Certificates. These certifications, defined in Table 2, do not represent an all-inclusive list, but are the primary certifications used to ensure public-use aircraft are designed, manufactured, tested, maintained, and operated in accordance with FAA standards.

Table 2: Typical FAA Certifications for Commercial Aircraft (FAA FAQ, 2011)

Certification	Description
FAA Type Certificate	FAA approval of the design of a specific aircraft (or aircraft engine, propeller, etc.). Authorizes manufacturer to make product in the specific way covered by the certificate. Major design changes require issuance of supplemental or amend type certificates.
FAA Airworthiness Certificate	Authorization from the FAA to operate an aircraft. This certification means the FAA considers the aircraft safe to fly.
FAA Production Certificate	Approval to duplicate products under an FAA-approved type design (type certificate or supplemental type certificate, for example).

Military aircraft are considered public aircraft, and as such are not subject to FAR and FAA oversight. However FAA Order 8110.101 and the 2007 MOA with the military departments specifically outline FAA support for MCDA. Although, in order for the FAA to remain involved, there must be a similar civilian fleet and the DOD must ensure the aircraft is operated and maintained according to FAA standards. If not, the MCDA will not retain its FAA Type Certification, as was the case with the C-130J (Stockman et al., 2011).

Recently, the Secretary of the Air Force implemented Air Force Policy Directive (AFPD) 62-6, "USAF Airworthiness", which outlines use of FAA certification with regard to commercial derivatives. The policy directive states,

> When a military mission is compatible with a certified civil usage, the AF will utilize FAA type certified commercial derivative aircraft (CDA) to the maximum extent practical. Commercial derivative aircraft whose primary mission is the transport of passengers shall be FAA type certified; FAA certification of these commercial derivative passenger carrying aircraft shall be maintained for the life of the air system. (AFPD 62-6, 2010:3)

While certification decisions will be made on a case-by-case basis, this guidance certainly supports FAA certification as part of DOD acquisition strategy and policy.

Military Certification

While the USAF can use FAA evaluations and inspections for their MCDA, any elements that do not meet FAA certification requirements will be certified via approved military airworthiness requirements. These requirements are outlined in MIL-HDBK-516B, which states,

> Commercial derivative aircraft (CDA) are initially approved for safety of flight by the Federal Aviation Administration (FAA) and may have an FAA approved Certificate of Airworthiness. Any non-FAA approved alteration to a CDA may render all FAA certifications invalid. While alterations to CDA are covered by

> rules unique to each branch of service, the operating service always has the responsibility for the airworthiness certification approval under public aircraft rules. (MIL-HDBK-516B, 2005:2-3)

In essence, regardless whether FAA certification is maintained or not, the policy states that the underlying responsibility for airworthiness certification compliance lies with the applicable service branch.

If FAA certification is not maintained, or for military certification of items not certified by the FAA, a Military Type Certificate (MTC) must be issued. Similar to an FAA Type Certificate, a MTC is a document that provides evidence that an aircraft system type design is in compliance with its approved certification basis. An Air Force official identified as a Technical Airworthiness Authority (TAA) is authorized to approve the certification basis (set of approved criteria, standards, and methods of compliance) and issue MTCs based on defined airworthiness standards. Following issuance of a MTC and evidence of safe operation, program managers issue a Military Certificate of Airworthiness (MCA) to each individual aircraft (AFPD 62-6, 2010). AFI 62-601, *USAF Airworthiness* (June 2010), which outlines the military certification process, states that the MCA "remains in effect for the approved service life as long as the air system configuration is in a condition for safe operation (i.e., properly maintained in accordance with approved maintenance documentation, and the system is operated in accordance with the approved flight manual and within the approved mission usage)." AFI 62-601 applies to all aircraft organizationally operated by components of the USAF.

Detailed criteria used in the determination of airworthiness for all manned, unmanned, fixed and rotary wing air vehicle systems are contained in MIL-HDBK-516B. This handbook not only identifies the DOD and military document references for each

requirement, but in many cases identifies the FAA counterpart to those documents as well. These dual references provide an indication that military certification requirements are often based on existing FAA requirements, and the two processes closely mirror one another.

Potential Costs of FAA Certification

Initial Certification

Typically, since MCDA are based off of previously certified aircraft designs and are already in production, they have already been certified by the FAA (Humerick & Minnich, 1992). As such, the question for decision makers is not whether to *obtain* FAA certification, but whether to *maintain* FAA certification (and for how long). This initial FAA certification is required in order for the aircraft to be operated and tested prior to being turned over to the military organization that purchased the aircraft. In some regard, because the costs associated with initial certification of MCDA have been paid, they might be considered *sunk costs*, or costs that are lost forever once they are paid (Baye, 2010). In other words, the military organization that purchased the MCDA would have to pay these costs regardless of whether the decision maker opted to keep the certification or not (Stockman et al., 2011).

In addition to the sunk costs associated with obtaining FAA certification are the *fixed costs* associated with maintaining it. Fixed costs do not vary with output and can include one-time purchases or upgrades (Baye, 2010). Costs associated with maintaining FAA certification that fall into this category might include those associated with updating military processes and procedures to allow for commercial parts pooling. For example, the costs associated with changing supply manuals and supply databases to enable

traceability of FAA approved aircraft parts might be substantial at first, but then might then reduce as military processes began to mirror those of the FAA.

Sustainment Strategy Dependent Costs

The costs associated with maintaining FAA certification are also heavily dependent on the overall sustainment strategy that will be used for the MCDA. Some sustainment strategies include organic (sustainment supported by U.S. government entities, such as DOD organizations), contractor logistics support (or CLS, or contractor provided sustainment), or a mix of the two. Another sustainment strategy is to transition from one type of support to another over the life cycle of the aircraft, such as starting with contractor support and transitioning to organic. These strategy choices are often influenced by other, much broader DOD requirements, such as the "50/50" requirements outlined in 10 U.S.C. Section 2466. This section of the code states the following regarding depot support for military aircraft:

> Percentage Limitation: Not more than 50 percent of the funds made available in a fiscal year to a military department or a Defense Agency for depot-level maintenance and repair workload may be used to contract for the performance by non-Federal Government personnel of such workload for the military department or the Defense Agency. Any such funds that are not used for such a contract shall be used for the performance of depot-level maintenance and repair workload by employees of the Department of Defense. (10 USC Sec. 2466, 2011:1)

In short, no more than 50% of depot funding may be used for CLS. Another significant influence on choice of sustainment strategy involves the identification of specific capabilities as *core* requirements, as defined below.

> Core: The depot maintenance capability (including personnel, equipment, and facilities) maintained by the Department of Defense at Government-owned, Government-operated facilities as the ready and controlled source of technical competence and resources necessary to ensure effective and timely response to a mobilization, national defense contingency situations, and other emergency

> requirements. Depot maintenance for the designated weapon systems and other military equipment is the primary workload assigned to DOD depots to support core depot maintenance capabilities. (DODI 4151.20, 2007:5)

The impact of the core identification label is simple: if the capability is identified as a core requirement, it must be maintained by government owned and operated facilities. Thus, regardless of which sustainment method may be the most cost effective, core requirements and 50/50 limitations can push sustainment decisions toward implementing less than optimal solutions.

Other Costs

Other costs associated with FAA certification (and the purchase of commercial derivatives in general) are numerous and are detailed in published guides for commercial derivative acquisition and commercial-off-the-shelf (COTS) purchasing. For example, as outlined in Gansler and Lucyshyn's "Commercial-Off-the-Shelf (COTS): Doing it Right" (2008), there are many challenges to consider before making COTS purchases. Item availability may be jeopardized as commercial vendors go out of business. Unanticipated technology changes can also lead to increases costs. Vendors may also substitute parts of a previously qualified component, creating a requirement for requalification. Additionally, COTS purchases may "lock the user into a proprietary technology…if an organization adapts a commercial ERP system, transitioning to another developer's ERP may be very costly" (Gansler & Lucyshyn, 2008:56).

The nature of the various costs mentioned in this chapter as being sunk or fixed is one of the reasons this research focuses on optimizing benefits as opposed to performing a specific cost-benefit analysis. Additionally, many of the costs are extremely situation-

specific and likely to change considerably on a case-by-case basis. As such, they are not conducive to being included the generic MADM support tool presented in Chapter Three.

Potential Benefits of FAA Certification

Participation in the Commercial Parts Pool

Perhaps one of the most significant benefits that comes from maintaining similar certification of MCDA to commercial fleets is the availability of the commercial *parts pool*. A parts pool is essentially a supply of parts that has been established for the use by a group or fleet of aircraft. By establishing a common pool of parts that all users can tap into, the level of spare parts inventory that each individual member must maintain can be reduced. This includes inventories for both operational use as well as safety stock. In order to participate in the commercial parts pool however, very specific FAA guidelines regarding repair and tracking of parts must be followed (Bongiovi et al., 2009). Specifically for MCDA, FAA certification must be maintained and participants must maintain the same airworthiness standards and criteria for those parts (Stockman et al., 2011). Specific guidance from the FAA on the subject of approving aircraft parts and parts-pooling states the following:

> An operator must ensure that all replacement parts meet or exceed original certification standards. Standard hardware and materials can be used and exchanged without special procedures. When special requirements must be met, accurate documentation must be maintained. Purchase, use, and exchange of parts require special procedures that must be part of the operator's manual, and in certain circumstances, part of the operator's operations specifications. (FAA Order 8900.1, 2007:2)

Further guidance can also be found in FAA Advisory Circular AC 20-169 which states that new, modified, or replacement parts produced for sale must be approved under the Type Certificate, a production certificate, a technical standard order authorization

(TSOA) or FAA letter of TSO design approval. It is absolutely critical that configuration control and proper tracking be maintained on all parts in the pool. For example, in order for used MCDA parts to be accepted back into the commercial parts pool, it must be shown that configuration control has been maintained and that all applicable requirements outlined in Title 14 Code of Federal Regulations Part 21 “Certification Procedures for Products and Parts” have been complied with.

There are several parts-pooling strategies that have been implemented in the past. One strategy is based on a one-way flow of parts, where FAA compliant parts can be purchased from a commercial pool and installed on USAF aircraft. These parts are not returned to the commercial parts pool once used because the aircraft or repair process involved did not meet FAA requirements. In contrast to this strategy is the two-way parts flow model which allows for shared use of FAA compliant parts (also known as “parts-swapping”). Other strategies include the Foreign Military Sales (FMS) Virtual Fleet model which allows for full parts-sharing among C-17 aircraft customers, for example, for parts managed by Boeing. The FMS Cooperative Logistics Supply Support Arrangement (CLSSA) model is an agreement between USAF and a foreign military service that establishes terms and conditions for follow-on spares support (AFMAN 23-110, 2009). Essentially, maintenance of the FAA type design (retention of the Type Certificate) can enable participation in these types of spare parts pools, which in turn can lead to decreased inventory costs and reduced aircraft downtime (Bongiovi et al., 2009).

Use of Existing Commercial Resources and Support

The benefit being described here is an extremely broad category that includes access to and utilization of commercial maintenance and supply resources, as well as

aircraft inspection and servicing capabilities. While utilization to existing supply and maintenance infrastructures is a benefit that can be associated with MCDA programs regardless of FAA certification, it should be included in the decision analysis as it can impact how long FAA certification should be maintained. Other important aspects of this benefit category are existing engineering resources that may be available in the commercial market for MCDA. Previous reports have identified that our government's continued reliance on its own engineering resources is less efficient than utilizing existing FAA procedures and personnel already available via commercial engineering support offices (Ross, 2010).

Access to Existing Commercial Data

This type of commercial data being referred to here is primarily the technical data used for modification (hardware, software, test data, design data, etc.). Access to this data requires negotiation of data rights with the original equipment manufacturer (OEM). This can be a fairly contentious issue during MCDA contract negotiations because the DOD typically wants to be able to modify their aircraft if they choose to do so, and believes that the data rights should be included in the purchase price. The subject of data rights is typically one of the most challenging with regard to MCDA programs (Bongiovi et al., 2009). If access to this type of data is not negotiated properly, costly reverse-engineering may have to be accomplished in order to recreate the manufacturing specifications and technical drawings.

Use of Existing Processes

Some of the existing processes in use by the FAA have proven to be very successful over time. Examples of the types of processes being referred to in this section

include FAA Service Bulletin and Airworthiness Directive processes, repair and inspection processes, as well as many other maintenance or safety related processes that have been proven in the commercial industry that may be applied to military operations.

Sale of Demilitarized MCDA to Commercial Market

The secondary market for previously owned military aircraft is dependent upon many factors such as aircraft type, age, fleet size, availability of similar aircraft, etc. If the sale or transfer of MCDA back to the commercial market is to be considered part of a budgeting strategy, the commercial value of the aircraft must be fully understood. Additionally, these aircraft must be maintained in a manner that preserves nearly identical functionality with to their commercial counterparts ("Buying Commercial," 2009). Maintaining FAA certification of MCDA is a big part of ensuring commercial commonality, as outlined in the following FAA Order excerpt.

> Ex-military aircraft now under civilian type certificates create parts problems, particularly when the original manufacturer has ceased production. Certain parts of original manufacture are available for a given aircraft for a number of years after its departure from military status. If original manufacturer fabrication can be substantiated for such parts, they are acceptable providing they comply with all applicable airworthiness directives. Certain parts for ex-military or currently manufactured aircraft are and have been scarce. Occasionally, parties other than the original or approved manufacturer produce these (FAA Order 8900.1, 2007)

Some of the processes and potential problems associated with demilitarizing military equipment are detailed in a Congressional Research Service (CRS) report to Congress from 2006. In this report, "Demilitarization of Significant Military Equipment," some of the issues identified included that the DOD had incorrectly coded military components, resulting in the sale of items that should never have been made available to the public. Obviously, extreme diligence must be exercised in carrying out

this disposal alternative, but if done successfully, it can be less costly than other alternatives. Ultimately, if it is feasible to dispose of excess DOD inventory in this manner, maintaining FAA certification may make this option less cost prohibitive.

Configuration Management

FAA regulatory and advisory guidance regarding aircraft configuration management, control, and tracking are extremely comprehensive. Details regarding evaluation and verification of aircraft configuration are outlined in FAA Order 8900.1, as well as several sections of the CFR. Some of the core issues with regard to aircraft configuration include verifying that the aircraft conforms to FAA approved type design, that it is a safe operating condition, and that substantiating records exist to show compliance with the operational compliance with Title 14 of the CFR (FAA Order 8900.1, 2007). While USAF configuration management is also well established, it can be more difficult to maintain due to the sheer number of different aircraft configurations in use. Some of the reasoning behind these difficulties was discussed in Stockman, Ross, Bongiovi, and Sparks' "Successful Integration of Commercial Systems: A Study of Commercial Derivative Systems" as outlined below.

> In some instances the Government has purchased certain CDA assets in very limited quantities, often including as few as one aircraft of a type per year. This practice, though sometimes necessary due to congressional appropriation constraints, results in higher costs for each individual CDA purchase and the creation of what the CDA industry terms ―partial orphan aircraft. That is, the configuration of most CDA systems in continuous production evolves on an annual or even more frequent basis, and this causes the Government's ―one-at-a-time purchasing practice of CDA systems over many years to put aircraft in the military service's fleets that are slightly or even significantly different in configuration (Stockman et al., 2011:179).

It is possible that increased FAA oversight in this area would potentially lead to process improvements and decreased risk from improved configuration control and documentation.

Quality and Safety

While the benefit of additional FAA oversight in the areas of quality and safety can be difficult to quantify, the sharing of best practices between similar organizations can lead to substantial cost savings and improved efficiencies. One of the major roles of the FAA is to promote safety through regulation of civil aviation. Additionally, FAA quality assurance is often used as the benchmark for military quality improvement efforts. The many years of experience the FAA has as an organization in these areas can bring substantial benefits. However, difficulty in quantifying these benefits often leads to underestimating the positive impact of maintaining a close cooperative partnership with the FAA.

Other Advantages to FAA Certification

As previously identified in this chapter, the potential benefits associated with maintaining FAA certification of MCDA are many, and this research effort does not represent an all-inclusive list, but there are a few more that deserve mention. For example, MCDA purchased by the USAF typically come with FAA certification as part of the purchase price. If major modifications are not made on the production line, the FAA Type Certification enables the military certification process to be completed more quickly, relative to aircraft that have not already been certified by the FAA. This allows for shorter turn-around time from delivery to operation.

Looking at the aviation industry from a broader perspective, some of the benefits to FAA certification of MCDA can also be viewed as they would apply to the international aviation industry. In other words, maintaining FAA certification for civil and military aircraft may represent a step toward establishing *international* airworthiness criteria that would be accepted industry wide. A study commissioned by the President of the United States and Congress in 2001 on the future of the aerospace industry highlighted several points on this subject in their final report, published in 2002. Some of these points are identified below.

1. Technology development and associated product cycle times have outpaced the applicable FAA regulations, policy, guidance and oversight capacity.
2. The time and cost to market for new technology communication, navigation, surveillance and air traffic management (CNS/ATM) products is prohibitive to the FAA's National Airspace System modernization plans and priorities.
3. The lack of international agreements concerning the interoperability of CNS/ATM products and the harmonization of applicable regulations is a barrier to defining International Airspace System U.S. Air Transportation System (INAS) operations and to any significant development or certification cost efficiencies for the associated products and systems.
4. Current methods, policies and practices do not support the types of operations necessary for efficient use of the INAS by the aviation community. ("Commission on the Future," 2002:pp. 2-4)

Based on these findings, the study went on to conclude the following:

> To transform our air transportation system, government and industry must work in partnership to enable certification regulations and processes that keep pace with advancing technical innovations. We must be able to efficiently certify the airborne information technologies, integrated systems, and communications links that will comprise our future system. ("Commission on the Future," 2002:2-5)

Methodology to Obtain Decision Support Tool Criteria Consensus

Various methods were considered regarding obtaining the right criteria to include in the decision tool. Initially, basic research into existing studies and reports was considered an appropriate method of determining the primary costs and benefits

associated with maintaining FAA certification of MCDA. Another method considered was to utilize a single advisor or expert in the subject matter to attempt to validate research findings. While this second method may have resulted in a certain level of uniformity in the responses, it was difficult to identify a single individual that had experience over all areas of the extremely broad topic of military aircraft acquisition and certification. Ultimately it was decided that, due to the extremely subjective nature of the research and decision criteria being considered, the most effective and efficient approach would be to achieve a consensus of subject matter experts through implementation of a Delphi study.

Delphi Study Techniques

By definition, the Delphi technique is "a series of repeated interrogations, usually by questionnaire, asked of individuals whose opinion or judgments are of value. The purpose is to arrive at a consensus regarding an issue under investigation." (Cornell, 1980:171) In short, a Delphi study is a technique used to elicit a group of responses from a panel of experts. The technique is very useful for instances in which quantification and analysis are difficult, and the approach to validating data will be primarily a judgmental one. In past applications, it has proven to be a useful method of pooling the knowledge and experience of participants in an anonymous way (Cornell, 1980). In fact, it is perhaps the anonymous aspect of the Delphi study that enables quality inputs to be received. Anonymity helps reduce the effects of socially dominant individuals or pressure from supervisors and peers to conform to a particular viewpoint (Dalkey, 1967). Essentially, the Delphi method replaces direct, face-to-face debate with "individual interrogations (best conducted by questionnaires) interspersed with information and

opinion feedback derived by computed consensus from the earlier parts of the program" (Brown, 1968:2).

Along with anonymity, there are two additional characteristics of a Delphi study that make it distinctive from other methods. One of these characteristics is *controlled feedback.* The term "controlled feedback" encompasses the method within a Delphi study wherein data collected over several iterations is summarized and "fed back" to participants in an effort to achieve consensus or at least reduce the level of disparity between responses. The third characteristic of a Delphi study is the idea of a *statistical index* or representative group opinion. This group opinion is typically the result of several iterations conducted with participants (Dalkey, 1967).

Typically, the Delphi technique is considered to have either two or four phases. Both approaches are similar, with the difference being that with the four-phase approach, the two primary phases (exploration and evaluation) are simply broken down further into four distinct steps. For example, the first three phases of the four-phase approach can be considered *exploratory* in that each participant contributes information (Phase 1) which is then clarified through iterations or feedback (Phase 2). If there are significant differences or disagreements then those areas are further explored to determine the underlying reasons behind them (Phase 3). Finally, *evaluation* occurs when all inputs are analyzed and fed back to the participants for consideration (Phase 4) (Linstone & Turoff, 1975).

Participant selection and panel size are important considerations to the Delphi technique. Delphi participants typically fall into one of three categories: *stakeholders, experts,* and *facilitators,* as defined here by Linstone and Turoff's "The Delphi Method: Techniques and Applications" (1975).

Stakeholders: Those who are or will be directly affected by outcomes or decisions.

Experts: Those who have an applicable specialty or relevant experience.

Facilitators: Those who have skills in clarifying, organizing, synthesizing, or stimulating.

Most panels consist of a mix of the three categories, and the proportion of each will vary from application to application, but a common trait throughout the group will likely be some level expertise in the subject of the study.

With regard to panel size, often one of the most critical criteria is the study timeline. As the size of the panel increases, the time allowed to each member to evaluate and respond decreases. This is primarily due to the fact that the level of complexity in summarizing and providing feedback for multiple iterations increases with panel size (Linstone & Turoff, 1975).

The key advantages to the Delphi study, anonymity and convenience, do not come without some trade-offs. Response levels are often affected by participant attrition, participant workload, and overall willingness (or lack thereof) to submit responses. Additionally, it is important to understand that the Delphi approach does not always result in consensus of the participants. While responses can be vague and subjective compared to other methods, it has been shown that often, the scientific technique behind many theories or hypothesis is often a somewhat philosophical basis (Linstone & Turoff, 1975). More important than reaching consensus is capitalizing on the level of expertise of the qualified participants and achieving a tool or model that is of value to the decision maker.

Multiple Attribute Decision Making (MADM)

Problems that involve multiple, conflicting criteria can become very complex as the number of criteria increases. In these types of situations, it can be helpful to have a model or tool that categorizes or prioritizes the criteria in some way. Multiple Attribute Decision Making (MADM) addresses this issue by helping to establish a method of "making preference decisions (e.g., evaluation, prioritization, selection) over the available alternatives that are characterized by multiple, usually conflicting attributes" Hwang and Yoon, 1995:2). As mentioned previously, the decision tool produced from this study utilizes some of the principles of MADM. The decisions or problems addressed by MADM can be very diverse, but a summary of some of the common characteristics, taken from Yoon and Hwang's "Multiple Attribute Decision Making: An Introduction" (1995) are outlined in Table 3.

In order to apply MADM, decision makers must often assign weights to the various attributes involved in their decision. These weights may be assigned in accordance with an ordinal scale (weighted by rank, as in 1st, 2nd, 3rd, etc.) or cardinal scale (weighted by a mathematical value), and while ordinal scales are usually simpler to assign, cardinal scales are preferred for MADM. Cardinal weights are typically normalized to sum to one. Through these methods of weighting, fairly subjective or qualitative attributes can be roughly quantified. For example, when applying weights to perceived benefits from a certain decision, greater weight value implies greater preference (Hwang &Yoon, 1995). While a simple application of relative weight based on preference or perceived value may seem arbitrary, such value judgments may be necessary, especially for complex problems. In fact, some problems even require such

value judgments in order to gain important insights that can only be achieved through value-focused thinking, or deciding which attribute is best and making the necessary choices to capitalize on that attribute (Keeney, 1992).

Table 3: Common MADM Characteristics

Characteristic	**Description**
Alternatives	A finite number of alternatives, from several to thousands are screened, prioritized, selected, and/or ranked. The term "attribute" is synonymous with "option," "policy," "action," or "candidate," among others
Multiple Attributes	Each problem has multiple attributes. A decision maker must generate relevant attributes for each problem setting. The number of attributes depends on the nature of the problem. The term "attributes" may be referred to as "goals" or "criteria."
Incommensurable Units	Each attribute has different units of measurement. For example, time or money may be expressed as units while safety or quality improvements might be expressed in a nonnumeric way.
Attribute Weight	Information regarding the relative importance of each attribute. Weights can be assigned or developed by methods utilizing ranks or ratios.
Decision Matrix	A MADM can be concisely expressed in a matrix format, where columns indicate attributes considered in a given problem and rows list competing alternatives.

For some decisions, applying cardinal weights in this manner allows for a more detailed look at the attributes. Not only are the attributes considered in order of precedence, but they are also considered by level of importance or impact as they relate to one another. Furthermore, by looking at a selection of attributes considered to have the most impact, they can be viewed in a simultaneous and hierarchical way. In other

words, sometimes it is not enough to simply compare two attributes as a choice of two alternatives. Sometimes in MADM applications, it may be necessary to consider all attributes at the same time in order to be able to make the necessary trade-offs between the available choices (Holloway, 1979).

Summary

In order to analyze complex decisions such as whether or not to maintain FAA certification of MCDA, decision makers must fully understand the background of the question as well as the process behind MCDA acquisition and certification. With so many variables to consider, it can be difficult for any single individual to fully grasp all aspects of the problem to the extent necessary to come to an optimal solution. For this reason, these types of decisions are seldom left to a single decision maker and are instead decided upon following detailed input from many experts from many different fields. This approach to decision making and weighing costs and benefits is based on some of the principles of the Delphi technique and MADM support tool utilized in this study. These are the methods outlined in Chapter Three that will help answer the following research questions:

Question 1: What are the decision criteria USAF leaders should consider when determining whether or not to maintain FAA certification of MCDA?

Question 2: How do the costs and benefits associated with maintaining FAA certification of MCDA change over time?

Question 3: If the choice is made to maintain FAA certification of MCDA, how long should it be maintained?

The answers to these questions, as based on the research and inputs received from subject matter experts, are provided in Chapter Four. These results are the basis for the conclusions and recommendations made in Chapter Five.

III. Methodology

Overview

This research attempts to answer the question of whether or not to maintain FAA certification of MCDA, and if so, for how long? In order to answer this question, several objectives must be met. First, the primary criteria that a decision maker uses to evaluate possible options must be established and well-defined. Next, those criteria must be ranked or assigned a level of importance relative to one another in order to determine their value when considering trade-offs. The final objective, determining attribute behavior over time, is perhaps the most difficult to identify due to its extremely subjective nature. It is fairly straightforward to identify the most important criteria in the FAA certification decision making process and then to rank or assign weight to each, however, once those criteria are identified and prioritized, they do not simply remain constant with respect to time. Therefore, it must also be an objective of this research is to show how the decision criteria behave or change over the lifecycle of the MCDA fleet.

Delphi Study

Objectives

There were several purposes for the Delphi study used in this research effort. The first was to elicit inputs from subject matter experts (SMEs) regarding what considerations a decision maker should make when determining if a commercial derivative was the right choice for a particular military acquisition. Additionally, it would be important to understand where a decision maker might perceive the greatest amount of risk regarding that initial commercial derivative purchasing decision. Following the decision to utilize a commercial derivative, SME inputs would also be

needed to determine what considerations a decision maker should make regarding maintaining FAA certification, and if there were any links between the risks associated with purchasing commercial derivative and those associated with maintaining FAA certification. This was an important aspect of the first Delphi questionnaire because initial research identified that some of the benefits associated with maintaining FAA certification may be perceived as an offset to the risks associated with using MCDA in general.

Another important objective of the Delphi study was to establish weight or impact level of the criteria involved in the FAA certification decision. While there are many methods of assigning such weight, the method chosen for this study was a simultaneous, non-hierarchical method in which a set amount of points (in this case, 100 points) were to be distributed among each of the criteria. The method was simultaneous in that all criteria were considered at once (as opposed to pairwise considerations of two criteria). Simultaneous weighting was used to eliminate the possibility of the participant providing conflicting weights, as can sometimes happen in a pairwise comparison. For example, in a pairwise comparison of several items it would be possible to assign weights such that Attribute A was weighted higher than Attribute B, and Attribute B higher than Attribute C, but then Attribute C contradictorily weighted higher than Attribute A at a later point in the weighting process. With simultaneous weighting of all attributes at once, this risk of this type of error is greatly reduced. The attribute weighting method was considered non-hierarchical in that there were no sub-categories of decision criteria, only a list of primary considerations or benefits. The attributes were listed in this manner because they were identified as the primary criteria in the decision process and as such, were meant to be

considered separately. Additionally, weights assigned in this type of non-hierarchical fashion can then be normalized to show their relationship with one another, as was done in this study.

Some level of bias was likely introduced into these weights based on participant background and behavior, and there are more complex methods of attribute weighting that may have been able to reduce some of this bias. However, for some multiple attribute decisions, the type of weighting method used is not nearly as important as participant selection and method of elicitation. There are many weighting methods that can be equally successful, so long as the attributes and the reason for applying weights are clearly understood by the study participants (Poyhonen, 1998). For this study, it was determined that using a more complex weighting method would have been only marginally more beneficial when compared to the amount of extra time needed to elicit responses. Taking into consideration the relatively short amount of time allotted to complete this study, as well as the high operations tempo and workload of the participants, the researcher instead decided to place extra focus on correctly identifying the attributes themselves, and ensuring the questionnaires were simple, easy to understand, and could be completed fairly quickly.

In order to conduct this type of study, the researcher completed the Human Subjects Research Training basic course through the USAF Research Laboratory. Additionally, because no demographic or sensitive data was collected during the course of the study, an exemption to the Federal, DOD, and USAF human experimentation requirements was approved (see Appendix P for Exemption Approval Letter).

Delphi Study Round One

There were three general purposes for the first round of study questionnaires (Appendix B):

1. Identify decision criteria used in determining whether or not a commercial derivative is the right acquisition choice

2. Identify the decision criteria used in determining whether or not to maintain FAA certification of MCDA
3. Identify the primary risk concerns a decision maker faces when making the decisions identified in items 1 and 2

Delphi Study Round Two

There were two general purposes for the second round of study questionnaires (Appendix E):

1. Assign simultaneous, non-hierarchical weights to the primary FAA certification decision criteria identified in Delphi study round one

2. Identify how FAA certification decision criteria behave or change over the lifecycle of the MCDA (based on the behavior curves provided in the questionnaire)

Participant Selection

In determining the size and make-up of the panel of participants, several criteria were considered. With regard to the panel's general make-up, two types of individuals were considered to be important to obtaining the type of feedback necessary for the topic of maintaining FAA certification of MCDA – *experts* and *stakeholders*. Experts are those individuals considered to have knowledge or experience relative to the subject, while stakeholders may be considered as those individuals who will be affected by the decisions made (Linstone & Turoff, 1975). For this panel, experts were chosen based on their knowledge and experience in USAF aircraft acquisitions and certification.

Stakeholders were chosen based on their involvement in current operations involving FAA certified aircraft or repair processes. In determining the optimal size of the panel, consideration was given to the overall timeline for the study while also keeping in mind that there is a point at which increasing the number of participants provides only marginal benefit to the relative value of the information provided. Additionally, examples of this style of Delphi study (for somewhat smaller organizations) consisted of panels of four to eleven participants.

Based on these factors, it was determined that approximately 20 participants would be sufficient to gather the information needed and an initial request for volunteers was submitted to four organizations. Initial responses received as a result of the research request memo (Appendix O) identified 18 volunteers, most having backgrounds in USAF acquisitions or experience with MCDA maintenance and operational processes. Positions held ranged from organizational to MAJCOM levels (Appendix Q), and most individuals had at least five years of experience in their current positions (with some having as many as 15 years). However, due to participant attrition over the range of the study, the final participant pool consisted of 13 individuals for round one (questionnaire one) and 10 individuals for round two (questionnaire two). Reasons for this attrition included participant retirement as well as failure to return completed questionnaires. Multiple attempts were made to re-engage with participants that did not return questionnaires (or returned incomplete questionnaires), but these attempts were largely unsuccessful. It is the opinion of the researcher that a high operations tempo and heavy workload may have been contributing factors to participant attrition. Those participants that provided incomplete responses (or no responses) were not included in the final results.

Delphi Study Design

Both Delphi questionnaires were administered via email to individual participants. Individual emails were used (as opposed to group or mass emails) in order to reduce the likelihood that the participants would discover the identities of the rest of the group. This would then potentially also reduce the likelihood that participants would communicate with (and possibly influence) one another. Each questionnaire was administered two times, with the second iteration incorporating some of the inputs from the first iteration in an effort to increase the level of concurrence. Due to the fairly short timeframe for the study, follow-up contact by phone was also made to ensure questionnaires were received and then returned in a timely manner.

The first questionnaire used for round one of the Delphi study included an introduction to the Delphi method, as well as a brief summary of the overall purpose of the research and statements outlining voluntary participation and confidentiality. As mentioned, the purpose of the first questionnaire was primarily to identify criteria and risks associated with USAF acquisition of MCDA and subsequent FAA certification.

The questionnaire contained three statements that were followed by five questions that attempted to identify the participant's stance or beliefs about those statements. The first two statements were a comparison of potential risks associated with the purchase of commercial derivatives early in the production cycle versus a purchase made later in production. The items of risk identified in these first two statements were a culmination of research into current sources on the subject. Questions #1 and #2 simply asked if the first two statements accurately represented the primary risks associated with USAF purchase of commercial derivatives, and if not, what items the participant felt should be

added or removed. Throughout the initial research for this study, a common theme had emerged that the benefits associated with maintaining FAA certification of MCDA was only relevant if there was a fairly large commercial fleet in use, and Question #3 simply asked if the participants agreed with this theme, and if not, why they disagreed. The final two questions (#4 and #5) on questionnaire one were developed as an effort to allow participants to provide open input regarding USAF purchase of commercial derivatives and subsequent FAA certification. Question #4 asked participants to provide comments or recommendations they would suggest to a decision maker regarding the decision to utilize commercial derivatives for military use. Question #5 similarly solicited suggestions participants would provide decision makers regarding the decision to maintain FAA certification. Overall, responses to these five questions were used to establish a list of criteria or attributes regarding benefits associated with FAA certification of MCDA.

The focus of the second questionnaire was to rank the attributes identified in questionnaire one and attempt to determine how those attributes might change over time. First, the attributes that were identified from questionnaire one were listed in no particular order. Participants were then asked to distribute 100 total points across all of the attributes, assigning points based on level of perceived impact. Participants were instructed to use all 100 points (no more and no less) in their effort to apply weights to the attributes. This method was chosen in order to not only allow the attributes to be ranked (1^{st}, 2^{nd}, 3^{rd}, etc.), but also to enable participants to distinguish various levels of importance. In other words, if participants felt that a certain attribute was extremely important or had a high level of impact, they could assign an appropriately high number

of points. For example, in a simple ranking, the relative difference between the first and second attributes is the same as the difference between the fifth and sixth. However, by utilizing an allowance of points, the difference between the first and second attributes might be 30 points, while the difference between the fifth and sixth might only be 5 points. This method of attribute weighting is a simple but effective means of identifying to a decision maker which attributes have the biggest impact and on what scale, relative to the rest of the attributes.

The focus of the second part of questionnaire two was to ask participants to identify how the attributes from the first part of the questionnaire behaved over time. In this questionnaire, participants were asked to consider a timeline that represented the lifecycle of an arbitrary fleet of aircraft that were already in production. A graphic timeline was provided that divided aircraft lifecycle into six segments. The segments were identified using common terms that all participants would be familiar with based on their backgrounds, and were labeled as follows:

1. Early Production
2. Mid Production
3. Late Production
4. Post Production
5. Commercial Retirement
6. MCDA Retirement

While an aircraft lifecycle typically begins much sooner than “early production” (such as the identification of a need for a particular capability, for example) and then progresses through various stages of design and requirement identification before entering production, MCDA can be viewed slightly differently. MCDA are by definition derivatives of previously developed commercial aircraft that are used for military

purposes, and as such, the lifecycle for use in this questionnaire begins with “early production” as opposed to “identification of need.”

In order to simplify the identification of attribute behavior with respect to time (or lifecycle), participants were provided with nine figures that each depicted an impact curve plotted against a timeline. The Y-axis or vertical axis of each graph showed level of impact, and the X-axis or horizontal axis of each graph represented time. Axis scale and label were designed to be extremely simple in order to make the graphs as generic as possible. For example, the level of impact (or Y-axis) had no numerical scale, and was simply labeled to show that the lower portion of the axis represented less impact while the upper portion of the scale represented more impact. Similarly, the timeline (or X-axis) had no numerical scale, but simply two points (A and B) that corresponded to specific points in the applicable curve, meant to be chosen from the provided timeline. A brief description of how the curves represented behavior over time was provided underneath each graph. The entire selection of nine graphs can be found in Appendix E, but a few examples are provided on the following pages for clarification.

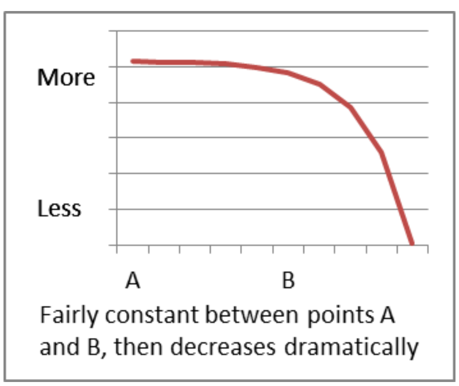

Figure 1. Example of Exponentially Decreasing Impact over Time

Figure 1 is an example of the graph provided to participants to represent a decreasing attribute impact over time. In this case, an exponential curve is used to show a fairly constant rate between points A and B, followed by a dramatic decrease after point B. Participants were asked to select two points from the six identified in the lifecycle timeline that best represented points A and B on the graph. For example, if one of the MCDA FAA certification decision criteria or attributes was the benefit associated with being able to participate in a common spare parts pool with the commercial industry, participants might identify this graph as a close representation of how the impact of those benefits would change over time. One might say that the impact of that benefit would be felt rather quickly once the commercial fleet reached mid-production, and then fall off dramatically once the commercial fleet retired. In that case, point A on the X-axis would represent "mid-production" (or "2" on the lifecycle timeline) and point B would represent "commercial fleet retirement" (or "5" on the lifecycle timeline). Once the participant selected the appropriate behavior graph and identified where points A and B fell on the lifecycle timeline, they entered that information into the table provided within the questionnaire. If the attribute impact increased in a linear manner or behaved in an exponentially increasing manner, then the participant might choose one of the graphs shown in Figures 2 and 3.

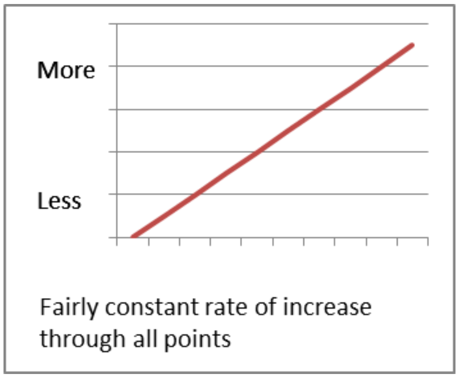

Figure 2. Example of Linearly Increasing Impact over Time

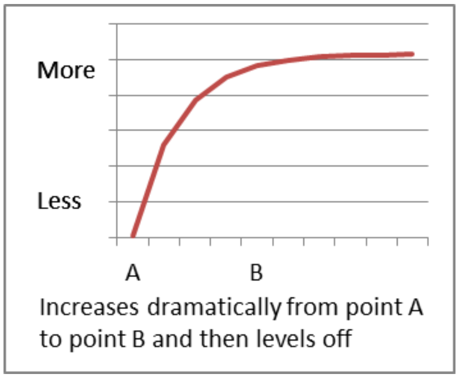

Figure 3. Example of Exponentially Increasing Impact over Time

Linear and exponential curves were chosen because they represented fairly common attribute behaviors. Additionally, there were curves provided in questionnaire two that represented a normal curve (increased to a peak and then decreased or visa-versa) as well as a flat line that represented little or no change over time. In an effort to maintain simplicity of the questionnaire, these several curves were determined to provide an adequate representation of attribute behavior for the purposes of this study, even though any number of additional curve types could have been provided. As can be seen in Figure 2 above, the linear representation does not have points A and B listed on the graph because it is meant to represent a constant rate of increase through all lifecycle

timeline points. Similarly, the linearly decreasing graph and flat (no change) graphs did not require participants to identify points A and B from the timeline.

Lastly, questionnaire two provided one final opportunity for participants to modify the list of attributes that had been previously identified in questionnaire one by asking them to view the list one last time and update areas as they felt necessary. This was meant to allow for finalization of the attribute list, in that participants could add, change, or remove items of their choosing if they believed items were incorrectly worded or falsely identified. Questionnaires one and two are located in Appendices B and E, respectively.

MADM Based Support Tool

Objectives

In order to graphically display the information collected by the Delphi study, a MADM based support tool was created (Appendix J). The tool is a simple model that couples attribute weights with behavior over time to produce an "impact score" for each of the six lifecycle points identified earlier. These scores were then converted to an easy to read bar chart identifying the relative benefit comparisons across the proposed fleet lifecycle (Appendix K). In short, the tool provides a decision maker with an approximate estimate of where he or she is likely to achieve the most benefit from maintaining FAA certification and at what point those benefits taper off. It also allows the decision maker a glimpse into which attributes are providing the highest level of impact at given times, so that the focus (or spending) can be shifted to different attributes depending on lifecycle position.

Using the example provided earlier regarding participation in the commercial spare parts pool, a decision maker might agree that the impact of this benefit would decrease rather significantly once the commercial fleet retired. If the weight of this decision attribute was rather large, say 40 points out of 100 (as determined by the Delphi panel of SMEs), then it would be extremely important to take this attribute into consideration, especially if the proposed commercial derivative acquisition was an older airframe and a new aircraft design was being introduced into the commercial market. This might indicate the commercial market was progressing toward retiring their fleet in favor of the newer model, leaving the USAF with an "orphan" fleet of aircraft that were no longer supported by commercial spare parts inventory. This is just one hypothetical example of the information the decision tool might be able to provide.

Decision Support Tool Design

The input portion of the decision support tool was designed very simply by using a Microsoft Excel-based table format. Microsoft Excel was chosen as a medium for constructing the tool due to its wide range of availability on government owned computer systems, allowing for ease of access and visibility by USAF personnel. The Excel table consists of the primary decision criteria or attributes for maintaining FAA certification (as identified in questionnaire one of the Delphi study), the average of the weights assigned to those attributes (taken from Delphi study questionnaire two inputs), and the behavior curves assigned to those same attributes (from questionnaire two). Each behavior curve is represented numerically by using applicable distributions (i.e. exponential, linear, constants, etc.).

Decision Support Tool Inputs

The leftmost column of the table contains a list of attributes that were identified in the questionnaires. The next column consists of the average of the weights assigned to those attributes, followed by their impact level based upon the SME assigned behavior curves. For example, if the behavior curve chosen for a specific attribute was an exponentially decreasing curve, the impact level assigned to each lifecycle stage would be the normalized value of the curve at each lifecycle stage. Linear curves would be similarly depicted using linear values between 0 and 1, with a value of 1 being assigned the curve that showed no change. Additionally, if a normal curve was chosen, then a normal distribution would be used to fill in these values.

Decision Support Tool Outputs

An overall *impact score* was computed by summing the products of the attribute weights multiplied by the numerical values of the behavior curves. These impact scores are displayed at the bottom of the table and are used in bar-chart format to show overall relative attribute impact over time. This impact score is simply meant to capture the shape of the behavior curve coupled with the weight of the attribute in order to provide a graphic depiction of the Delphi study responses. Utilizing weights to assign impact scores or impact grades is common in decisions with multiple attributes (Lootsma, 1999).

Validation

Questionnaire one consisted of statements and comments that were considered to be within the realm of common knowledge of the study participants, so no confusion was anticipated with regard to participants being able to complete it in a reasonable amount of time. However, since questionnaire two was slightly more complex, it was first

administered to another research student as a means of testing ease of understanding and completion time. The student was not provided any background information, but was simply asked to complete it by following the directions provided on the questionnaire. After reading the instructions for about five minutes, the student was able to complete the questionnaire in approximately 15 additional minutes without assistance. Based on this result and the fact that the actual study participants would have more background and experience with the material, the researcher anticipated that similar results would be seen when the questionnaire was administered to the actual study participants.

Challenges

Complex decisions such as the ones being analyzed here have some inherent challenges that should be highlighted. Perhaps the biggest challenge with regard to this study was creating a decision support tool generic enough to have a wide range of applicability, but not so generic that it was of little or no value to the decision maker. With that in mind, it is important to understand that each and every decision regarding military purchase of commercial derivatives and the subsequent decision of whether or not to maintain FAA certification is going to have attributes that are unique to the specific situation. Factors such as mission requirements, budget levels, and political direction are extremely dynamic and have a great deal of influence on USAF aircraft acquisitions. These types of internal and external factors are not constant, and while it may be possible to make point-in-time approximations, they can fluctuate dramatically over the course of a complex decision-making process. Because of this, the questions asked during the various phases of the Delphi study were purposefully broad and meant to solicit responses that were general in nature. It would be nearly impossible to create a

single decision support tool capable of providing information applicable to every possible MCDA acquisition scenario.

Additional challenges came from trying to accurately identifying the costs associated with maintaining FAA certification. As mentioned previously, many of these costs would be considered sunk, fixed, or one-time costs that might lead to incorrect assumptions if considered equally across all FAA certification decisions. For example, the sunk cost associated with initial FAA certification is typically factored into the purchase price of the aircraft regardless if the USAF decides to maintain that certification. By definition, that cost is considered "sunk" because it will not be saved if the USAF decides not to maintain FAA certification. As such, it should not be factored into the decision support tool. A similar challenge arises with regard to the fixed and up-front costs associated with modifying USAF supply databases to enable tracking of FAA certified spare parts. These types of costs would be much higher for the first commercial parts-pooling endeavors, but would be relatively lower for successive MCDA acquisitions because the infrastructure would already be in place. Trying to incorporate these types of costs would likely skew decision support tool outputs. Due to the nature of these challenges, the focus of the tool was on potential *benefits* associated with maintaining certification, and how their impact as decision attributes changes over time.

Summary

The Delphi technique was well suited to the qualitative nature of this study. Providing clear, easy to understand questionnaires that were relatively easy to complete was an essential part of ensuring maximum participation, especially considering the high operations tempo and heavy workloads of the participants. Proper participant selection

was instrumental in correctly identifying the decision attributes used in the tool. Their strong background in USAF aircraft acquisition processes as well as front-line experience with FAA certified MCDA and repair processes enabled direct and meaningful feedback to take place and helped mitigate many of the challenges faced during the course of the study. Any insight gained from utilization of the decision support tool is a direct reflection of the valuable inputs received from each and every participant. The results and conclusions that were made based upon these inputs are discussed in detail in the next two chapters.

IV. Results and Analysis

Overview

Over the course of several months, Delphi questionnaires one and two were submitted to each of the participants, revised based on their inputs, and finally re-submitted once more for review in order to try and achieve consensus. After both questionnaires had gone through this iteration process, the revised (final) inputs were analyzed and used to build the decision support tool and subsequent figures, charts, and tables.

Delphi Study

Questionnaire One Results

Based on the three purposes for questionnaire one mentioned earlier, two general statements regarding the risks associated with USAF purchase of commercial derivatives were made at the beginning of the questionnaire (Appendix B). A third general statement was made regarding the impact of commercial fleet size on potential FAA certification benefits. Statement one had two parts (1A and 1B), statement two had three parts (2A, 2B, and 2C), and the third statement had one part. Questions #1 through #3 asked each participant if they agreed with those statements, and if not, to provide justification for their disagreements. These first three questions helped establish the topic and direction of the questions that followed, as well as establish a baseline of knowledge to ensure all participants agreed on some of the basic background information regarding commercial derivatives and FAA certification. The final two questions (#4 and #5) on this questionnaire were open-ended and asked each participant to provide additional recommendations for decision makers considering the purchase of commercial

derivatives and subsequent FAA certification. These two questions were included as an effort to ensure no important decision criteria would be neglected or left out of the list of attributes for the decision support tool.

Results obtained from the first iteration of questionnaire one were mixed, as shown in Table 4 and Appendix C. As mentioned earlier, although the initial participant pool consisted of 18 individuals, five were lost very early due to attrition, leaving a total of 13 participants for questionnaire one. Also, since questions #4 and #5 were open ended questions that did not solicit an "Agree" or "Disagree" response, the columns in Table 4 for those questions are not applicable.

Table 4. Questionnaire One Results (First Iteration)

Question	**Agree in Full or Agree with Comment**	**Disagree**
1A	10	3
1B	10	3
2A	11	2
2B	7	6
2C	11	2
3	6	7
4	N/A	N/A
5	N/A	N/A

Based on the mixed response received on statements 2A and 3, both statements were modified to incorporate additional participant comments. The modified statements can be seen in Appendix D. Since an overwhelming majority of participants agreed with the remaining statements, they were left unmodified and not submitted as part of the second iteration. By only re-submitting modified statements in the second iteration, participants did not have to spend time re-reading information they had already commented on and impact on participant workload was minimized. The two modified

statements were resubmitted to all participants, resulting in a much higher level of consensus, as shown in Table 5. All additional comments were carefully considered to determine if any further modification was needed.

Table 5. Questionnaire One Results (Second Iteration)

Question	**Agree**	**Disagree or Agree with Comment**
1A	10	3
1B	10	3
2A	11	2
2B (Modified)	**13**	**0**
2C	11	2
3 (Modified)	**12**	**1**
4	N/A	N/A
5	N/A	N/A

The open-ended inputs received from questions #4 and #5 were compiled and then used to build upon and confirm preliminary research that had been accomplished in the area of FAA certification decision criteria.

Due to the nature of the *costs* associated with FAA certification that was discussed previously, decision criteria were primarily focused on the potential *benefits* of maintaining FAA certification. The decision criteria (listed as “attributes” in the decision support tool) are identified below, in no particular order, using the same verbiage and sequence that was used on the questionnaire. This list contains the ten attributes that have the most impact on the decision to maintain FAA certification, as determined by the Delphi study participants. When given an opportunity to add more attributes to this list, none of the participants did so, which may indicate that the list captures a majority of the benefits associated with maintaining FAA certification.

Decision Criteria (or "Attributes") List

1. Participation in the commercial parts (spares) pool
2. Access to established commercial maintenance support and infrastructure
3. Access to an established commercial supply chain
4. Use of existing manuals, repair/failure data, and technical data
5. Use of existing FAA approved processes (Service Bulletin and Airworthiness Directive processes, repair processes, etc.)
6. Improved control and tracking of aircraft configuration data
7. Ability to participate in cross-servicing with European Aviation Safety Agency (EASA) and FAA fleets
8. Ability to sell demilitarized MCDA back to commercial market
9. Reduced need to acquire proprietary OEM design data or flight test data
10. Improved safety due to increased FAA oversight

With the vast majority of participants now in agreement with the statements on the first questionnaire, as well as all decision criteria properly identified and all inputs compiled regarding additional recommendations for decision makers, round one of questioning was considered complete. A complete record of all inputs can be found in Appendix C.

Questionnaire Two Results

Questionnaire two (Appendix E) was divided into two parts based on the purposes outlined for this questionnaire that were mentioned earlier. The first part consisted of a weight identification chart for the decision criteria (from questionnaire one). This simple chart listed the primary FAA certification decision criteria (10 in all) in the left column with a blank "weight score" column on the right. Participants were asked to distribute 100 points total across all 10 criteria. Weight scores and averages can be found in Appendix F, however Figure 4 is a pie chart depiction of those averages (as a percentage of the total), with abbreviated attribute titles listed by order of weight (highest to lowest) on the right of the figure. As can be seen in Figure 4, the top three attributes combined

weights, as assigned by the SMEs, represent nearly half of the 100 points allotted. Additionally, the top five attributes were assigned nearly three-quarters of the total weight allotment. This distribution of weights helps to confirm that a simple rank-order of attributes (i.e. 1 through 10) would not have sufficiently captured attribute impact. Instead, the top five attributes are considered to have disproportionately more impact on the decision to maintain FAA certification than the bottom five attributes.

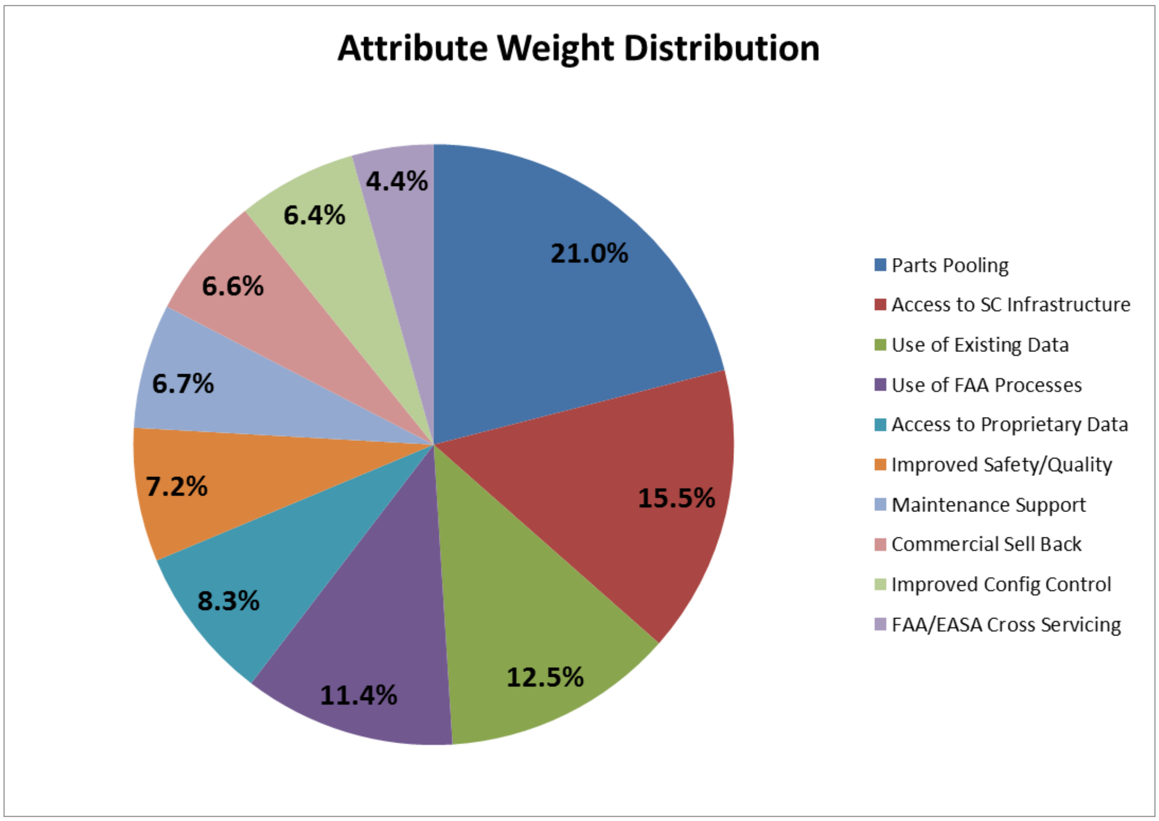

Figure 4. Attribute Weight Pie Chart

Across most of the participants, weights assigned were very similar for each attribute, and in fact, most weight values fell within a 10-point range with only a few outliers. The presence of outliers is likely due to varying interpretations of the attribute

definitions. This variation is one of the risks associated with using fairly ambiguous or qualitative data. Overall, two attributes had all values fall within a 10-point range, four attributes had a single outlier, three attributes had two outliers, and one attribute had three outliers, as depicted in Table 6. The individual values of these outliers are also shown in the table.

Table 6. Attribute Weight Range and Number of Outliers

Attribute	Assigned Weight Range	Number of Outliers	Outlier Values
Parts Pooling	15 – 25	3	5, 35, 40
Access to SC Infrastructure	10 – 20	0	N/A
Use of Existing Data	5 – 15	1	30
Use of FAA Processes	5 – 15	1	30
Access to Proprietary Data	0 – 10	2	25, 30
Improved Safety/Quality	0 – 10	2	15, 25
Maintenance Support	0 – 10	0	N/A
Commercial Sell Back	0 – 10	1	25
Improved Configuration Control	0 – 10	2	12, 15
FAA/EASA Cross Servicing	0 – 10	1	15

The second part of the questionnaire consisted of a fairly complex scheme of figures and questions designed to help determine individual attribute behavior over time. This section asked participants to select from an assortment of attribute behavior curves that they felt best identified the correct behavior for each attribute over time. Two points were included on the non-linear curves to allow participants to assign transition points based on the lifecycle timeline provided (linear curves have no distinct transitions, and thus no need for the transition points). With 10 attributes for example, 10 curves and 10

sets of points (linear curves excluded) were selected representing fleet lifecycle stages. Despite the relative complexity of this questionnaire, it appeared that the study participants understood the meaning behind the curves, since their selections anecdotally appeared consistent with what would be considered intuitive with regard to the attributes. For example, the attributes that would be dependent on an active commercial fleet were assigned curves that displayed diminishing levels of impact as the commercial fleet entered retirement. As with the first questionnaire, results were mixed, but some common themes could be seen, especially among some of the top weighted attributes. When the results of questionnaire two were compiled and re-submitted to the participants in the second iteration (in an attempt to improve concurrence levels), none of the participants made any changes to their answers, and thus questionnaire two was considered to be complete.

With 10 inputs received from this second questionnaire, focus was first given to attributes in which at least half the participants agreed on a behavior curve. Interestingly, this was precisely the case with five of the six top weighted attributes. In other words, when ranked by weight, attributes 1, 2, 3, 4, and 6 (as identified in Figure 4) had behavior curves that were agreed upon by at least half of the Delphi study participants. Considering that there were a total of nine curves to choose from, this was determined to represent a fairly strong concurrence. Additionally, the lifecycle timeline points chosen (from six available) were also very closely matched among these same attributes. These results can be seen in Appendices G, H, and I, but a summary of these specific five attributes (listed by highest to lowest average weight) can be seen in Table 7. As a reminder, linear behavior curves (behavior curves #7, #8, and #9 on questionnaire two)

did not require selection of lifecycle timeline points, and as such, do not have values listed in those table columns.

Table 7. Attribute Behavior Curve Comparison (Minimum 50% Concurrence)

Attribute (abbreviated title)	**Behavior Curve Shape (chosen by at least half of participants)**	**Behavior Curve Point A (chosen by at least half of participants)**	**Behavior Curve Point B (chosen by at least half of participants)**
Parts Pooling	4	2	5
Access to SC Infrastructure	4	2	5
Use of Existing Data	8	N/A	N/A
Use of FAA Processes	8	N/A	N/A
Improved Safety/Quality	8	N/A	N/A

For the “parts pooling” and “access to supply chain (SC) infrastructure” attributes shown in Table 7, behavior curve #4 was an exponentially decreasing curve. Point 2 on the lifecycle timeline represented the mid-production stage and point 5 represented the stage at which the commercial fleet began to retire. Curve #4 is shown in Figure 5 below.

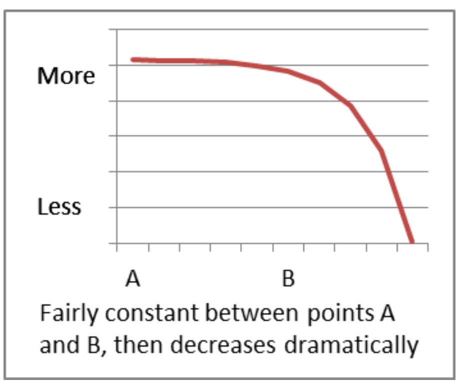

Figure 5. Behavior Curve #4 from Questionnaire Two

For these two criteria, it can be seen in Figure 5 that at least half of the participants felt that the benefits associated with the "parts pooling" and "access to SC infrastructure" attributes were fairly constant from mid production until the beginning of commercial fleet retirement, but then decreased dramatically.

For the remaining three criteria in Table 7, behavior curve #8 was chosen. Curve #8 (Figure 6) is simply a flat line that depicts no change over time. In other words, most participants agreed that the benefits associated with these three attributes were fairly constant over the lifecycle of the fleet. Note that there are no transition points in curve #8 because the rate is fairly constant through all lifecycle timeline points. Appendix L shows a graphic depiction of how these five attributes behave over time.

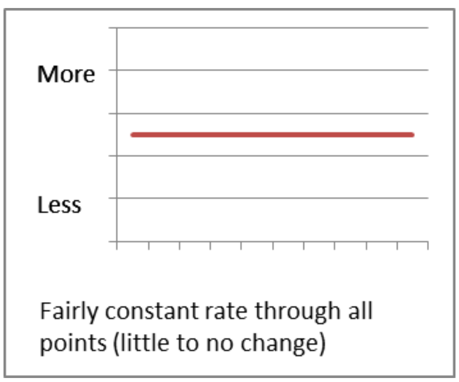

Figure 6. Behavior Curve #8 from Questionnaire Two

Behavior curve selection for the remaining attributes was much more mixed, and while a majority concurrence was not achieved, there were curves that were selected more often than others. For example, the attribute that was weighted the fifth highest, "access to proprietary data," had behavior curve #4 chosen more often than any other curve. Additionally, Point A was identified as "early production" by in all cases that

curve #4 was chosen. Point B was identified as “begin MCDA retirement” most often by those that chose curve #4. Results for the remaining attributes are shown in Table 8, and complete results for all attributes can be found in Appendices G, H, and I. It is important to note that the transition points (A and B) identified in Table 8 are not necessarily the ones that were chosen most often among all participants, however they were the ones chosen most often with the associated curve shown in the table.

In order to provide a slightly different perspective, the responses to questionnaire two were divided into two groups based on the positions held by the participants at the time. One group included responses from participants whose jobs were primarily related to the field of *acquisitions,* while the second group included responses from participants whose jobs were primarily *sustainment* related. Interestingly, even after separating the groups in this manner, the top three attributes (as ranked by assigned weight) for both groups were the same as before the separation: “parts pooling,” “access to supply chain infrastructure,” and “use of existing data.” However, with the sustainment related group, “access to proprietary data” and “commercial sell back” replaced “use of FAA processes” and “access to maintenance support” as attributes ranked fourth and fifth. With the acquisitions related group, “access to maintenance support” replaced “improved safety/quality” as the fifth attribute. Graphic depiction of these results can be seen in Appendices M (sustainment) and N (acquisitions). Of note in Appendix M is the relatively short window of impact for the “commercial sell back” attribute, due to the associated behavior curve. It is also important to note that these two additional graphs were only created to compare the differences in weight assigned by the two groups, and that the curves used to create the graphs were from Tables 7 and 8, as applicable.

Table 8. Attribute Behavior Curve Comparison (Non-Majority Concurrence)

Attribute (abbreviated title)	**Behavior Curve Shape (chosen most often by participants)**	**Behavior Curve Point A (chosen most often with associated curve)**	**Behavior Curve Point B (chosen most often with associated curve)**
Access to Proprietary Data	4	1	6
Maintenance Support	4	2	5
Commercial Sell Back	6	4	5
Improved Configuration Control	8	N/A	N/A
FAA/EASA Cross Servicing	8	N/A	N/A

Decision Support Tool

As shown in the Decision Support Tool in Appendix J, attributes that were identified as having their behavior over time associated with curve #8 (little to no change) were given a constant impact score of 1 for all lifecycle stages. There were five attributes in this category. Four of the remaining attributes were identified as having their behavior over time associated with curve #4. This was an exponentially decreasing curve that was fairly constant between the two transition points (A and B) followed by a dramatic decrease. In three of these cases, points A and B were identified to be “mid production” and “commercial retirement” respectively. As such, an exponential distribution was used to determine the *impact level* values for the first five lifecycle stages, dropping off to zero for stage 6. In the fourth case where curve #4 was chosen, transition points A and B were identified to be “early production” and “begin MCDA retirement” respectively. In this case, an exponential distribution was used to determine impact level values across all six lifecycle stages. In other words, due to the different choice for point B in this case,

impact level value did not drop off to zero, as in the first three cases of curve #4. For the final attribute, curve #6 was chosen which depicts exponential decrease between points A and B. In this case, point A was identified to be "post production" and point B was identified to be "begin commercial retirement." Due to these late-cycle selections for transition points, impact levels prior to "post production" were set at zero, followed by exponentially decreasing values for the remainder of the timeline. All of these results are more clearly identified in Appendices G, H, and I.

Lifecycle Impact Score

By computing the product of impact level and attribute weight values, an impact score was obtained for each attribute at every stage of the lifecycle timeline. In other words, with 10 attributes and six lifecycle stages, a total of 60 impact scores were obtained. Impact scores for each lifecycle stage were summed, resulting in a value that represents the combined impact of all attributes at each given stage. A summary of these values is shown in Table 9.

Table 9. Combined Lifecycle Impact Scores

Lifecycle Stage	Early Production	Mid Production	Late Production	Post Production	Begin Commercial Retirement	Begin MCDA Retirement
Impact Score	92.97	92.45	91.07	93.54	77.18	47.20

Attribute Impact Lifecycle Behavior

As shown in Appendix K, these combined impact scores dip slightly from early to mid-production, and then again from mid to late production. They then peak during post production, followed by a dramatic decline at the beginning of commercial fleet

retirement. This dramatic decline continues through the beginning of MCDA retirement. These values were used to create a graphic depiction of attribute impact relative to the lifecycle timeline, as shown in the chart in Appendix K.

Summary

There are many challenges associated with achieving majority consensus over the course of a fairly short Delphi study, and these challenges become even more apparent when the data collected is qualitative in nature. Overall, two rounds (or questionnaires) were deemed sufficient to gather the necessary information to construct and populate the decision support tool. Considering the participant attrition that was already occurring after two rounds, a third round of questions would likely have not provided a significant amount of additional information. Additionally, varying interpretations and opinions can often lead to a wide range of differing responses, especially when the study participants have extremely diverse backgrounds, as in this study. Despite these challenges and diversification, however, many responses to questionnaires one and two were surprisingly similar. For example, the final list of attributes used to create the decision support tool was agreed upon by all participants. The weight scores assigned to these attributes were also very close. While the selection of behavior curves and transition points varied greatly for some attributes, they were fairly similar for the attributes with the highest weight. This similarity allowed for some simple but useful conclusions to be drawn from the data, discussed further in the next chapter.

V. Discussion

Overview

As stated in Chapter 1, the primary objective of this research was to helps identify criteria that USAF leaders and decision makers could use to determine whether maintaining FAA certification of MCDA was beneficial when compared to maintaining only military certification. In order to fulfill this objective, three research questions had to be answered.

Question 1: What are the decision criteria USAF leaders should consider when determining whether or not to maintain FAA certification of MCDA?

Question 2: How do the costs and benefits associated with maintaining FAA certification of MCDA change over time?

Question 3: If the choice is made to maintain FAA certification of MCDA, how long should it be maintained?

Question 1 was answered through the participant responses received from Delphi questionnaires one and two that validated a list of 10 decision criteria for decision makers to consider when determining whether or not to maintain FAA certification. These criteria represented the attributes for the MADM support tool described in Chapter 3 and seen in Appendix J. As outlined in Chapter 2, the focus of the attributes was on the potential benefits of maintaining FAA certification, since costs associated with FAA certification were primarily sunk, fixed, or one-time (up-front) expenses. Question 2 was also answered through participant responses received from Delphi questionnaire two, where attributes were assigned a weighted value and then matched to behavior curves that identified changes over time. This data represented the second set of inputs to the

MADM support tool. Finally, the output of the MADM support tool (Appendices K and L) provided the answer to Question 3 by displaying graphic representations of attribute impact over the typical lifecycle of a fleet of aircraft. These graphs allow decision makers to not only identify which attributes have the most impact, but at what point during the lifecycle timeline impact levels diminish.

Conclusions

Looking solely at the weight values assigned to the 10 attributes, decision makers can conclude that most of the SMEs that participated in this study feel that participation in a commercial parts (spares) pool and access to a well-established commercial supply chain are the two attributes that have the most impact on the decision to maintain FAA certification. In fact, these two attributes alone account for more than 35% of the total weight of all attributes. However, weight value should not be considered without also taking into account the diminishing nature of these attributes, as indicated by their behavior over time. In this case, impact of these two attributes diminishes rapidly as the commercial fleet enters the retirement stage of the fleet lifecycle. Take for example, a MCDA purchased near the end of production. Consider also that the decision maker is considering maintaining FAA certification of that MCDA. The decision maker is also considering allocating a portion of the budget to pay the up-front costs associated with upgrading military supply databases and spare parts tracking regulations in order to take advantage of commercial parts pooling opportunities. By analyzing the output of the decision support tool, the decision maker can see that there is a fairly short window of opportunity to take advantage of the benefits associated with that decision. The decision maker can also see that as the commercial fleet begins to retire, a very large portion of

those benefits diminish rapidly, which greatly reduces his or her return on investment. The attribute associated with access to proprietary OEM design data or flight test data behaves in a similar diminishing fashion, however not as quickly.

In another scenario, the MCDA in question might be in the mid-production stage leading the decision maker to believe that the cost of maintaining FAA certification will be offset by the benefit associated with access to established commercial maintenance support and infrastructure. While it is true, according to SMEs in this study, that such access is beneficial, this particular attribute was assigned less than 7% of the total weight, as compared to the other attributes. If access to maintenance support is the primary decision criteria being considered, then the cost of maintaining FAA certification may not be justified in this case. On the other hand, if use of existing manuals and repair data or use of existing FAA processes (such as service bulletin/airworthiness directive and repair processes) are the primary decision criteria being considered, the decision maker can see that these two attributes not only represent nearly 24% of assigned weight, but also that their impact level remains fairly steady over time. In other words, according to the SMEs that participated in this study, the benefits associated with these two attributes do not depend on what stage of the lifecycle timeline the particular MCDA happens to be in.

A final scenario involves the attribute associated with selling the MCDA back to the commercial market. Maintaining FAA certification of the MCDA throughout its military lifecycle makes this a much simpler process due to ease of records transfer, maintenance tracking requirements, etc. However the MADM support tool shows a very short window of opportunity for this benefit coupled with a low weight score. While still a valid benefit, it does not rank very high when compared to other benefits. The impact

levels of the remaining benefits were determined to remain fairly constant over time by varying degrees of consensus of the Delphi participants (as shown in Appendix G). These remaining attributes also represent the lower end of the weight scale.

Assumptions and Limitations

While the overall goal of this research is to identify potential benefits that can be achieved through USAF collaboration with the FAA and commercial industry, some of this research also focuses on potential improvements that can be made. As such, the level of impact of some of the potential benefits outlined is dependent on individual circumstances. For example, it is assumed that if the criteria are met for the USAF to *access* the commercial parts pool for a particular MCDA, the commercial industry will *allow* that access. In other words, maintaining FAA certification does not in and of itself guarantee the benefits associated with that certification. Agreement in these areas must be obtained from all parties involved. Additionally, it is beyond the scope of this research to provide an all-inclusive decision making tool for all situations regarding FAA and military certifications, but certainly there are specific costs and benefits that are analyzed and explained that will help decision makers choose the appropriate course of action. The information provided might be used as a heuristic that, when combined with other applicable information, can provide further insight into the consequences of the certification choices, while also acting as a guide to a more accurate and optimal course of action.

There are numerous challenges inherent in trying to simplify decisions with many variables. In this case, the variables that make up decision criteria involved in determining whether or not to maintain FAA certification of MCDA are both dynamic

and somewhat ambiguous, and as such are hard to quantify. Extensive research on exactly how the commercial market can support DOD logistics is not readily available, and successful examples of FAA certified MCDA have not been thoroughly captured and analyzed in terms of real costs and benefits. In fact, most DOD aircraft drop the FAA certification after military certification is achieved, leaving the military customer with an “orphan fleet.”

Additionally, due to short timelines, high operations tempo, or manning constraints, there is typically not enough time to conduct an adequate amount of market research prior to new aircraft acquisitions. Other factors that may negatively affect a decision maker ability to choose the most optimal solution include 50-50 requirements as outlined in Title 10 United States Code Section 2464, which requires 50 percent of depot operations and facilities to be government owned and operated by government personnel. While this reduces some of the risk associated with the government having too much dependence on the commercial market, it may prevent decision makers from being able to take advantage of existing commercial resources. While this type of restriction may have been necessary at one time, some would argue that it is no longer justified, given the current market’s flexibility and response capabilities (Stockman et al., 2011).

Other challenges emerge when military capabilities are declared “core,” meaning that they are essential to military operations, and as such must be supported by military infrastructure and personnel. For example, the USAF latest MCDA acquisition, the KC-46 tanker (commercial derivative of B767), may be declared “core” despite existing commercial infrastructure and support. Such a decision would drastically increase overall lifecycle sustainment costs. Another example can be seen with the USAF

acquisition of the C-27J, which was declared core despite a business case analysis that stated CLS would be more cost effective for sustainment. During the early stages of these types of acquisitions, requirements to comply with Federal Acquisition Regulations (FAR) also leads to increased administrative costs that may be unnecessary.

Recommendations

It is recommended that the MADM decision support tool presented in this research be incorporated as part of the FAA certification decision making process. This tool is not meant to represent an all-inclusive guide to determine the appropriate response to such decisions. It is meant to be used as a reference to achieve an additional level of understanding into FAA certification decision criteria and how they behave over time. It is also recommended that decision makers review the complete responses provided to both Delphi study questionnaires, as they may provide additional insight or help guide the decision maker to a more optimal solution. The complete record of questionnaire responses can be found in Appendices C, D, G, H, and I.

Areas for Future Research

Due to the high amount of weight assigned to the two attributes associated with access to commercial parts and the commercial supply chain, a potentially beneficial area for future research would be to take a closer look at the costs associated with upgrading military systems to take advantage of that access. The relatively short timeline of this research did not allow for adequate investigation into this area. By obtaining a rough estimate of this cost, future decision makers may be able to justify allocating a portion of the budget to this purpose. It is possible that the cost may be too great to be offset by an

existing MCDA fleet, but instead would be offset over the course of several future MCDA purchases.

An additional area for future research would be to expand this topic to include all branches of military service. For example, the U.S. Navy also has MCDA currently in use and valuable insight would be gained by including Navy personnel as participants in the Delphi study. Including all military branches would facilitate the sharing of lessons learned and best practices. Finally, as discussed in Chapter 1, it may also be beneficial to also look into streamlining the certification process itself. The process has evolved into a very complex set of procedures and requirements and might become more efficient if simplified. It may also be beneficial to look at the Military Type Certification process that occurs when FAA certification is not maintained.

Summary

The decision regarding whether or not to maintain FAA certification of MCDA is certainly not an easy one to make. Decision makers may not always have a complete picture that accurately outlines the costs and benefits of their choices. Heavy workloads coupled with a high operational tempo can detract from the time needed for adequate research, and when coupled with a tight timeline, the situation can lead to a less than optimal outcome. Additional challenges are presented when the information that is available is vague or difficult to interpret, depending on one's background and experience. However, the potential benefits of collaboration in the area of certification can be substantial, particularly as we continue to build a more global economy and increase the need to collaborate on an international level. Only when decision makers

have all the information they need to identify these cooperative opportunities will they be in a position to take full advantage of them.

The MADM support tool developed as part of this research coupled with the participant responses to the Delphi questionnaires provides the answers to the original research questions outlined in Chapter 1. While somewhat generic in nature, the MADM support tool nonetheless provides further insight into the decision criteria and may be used as part of an overall decision making strategy.

Appendix A. List of Acronyms

CDA – Commercial Derivative Aircraft
CLS – Contractor Logistics Support
CLSSA – Cooperative Logistics Supply Support Arrangement
CNS/ATM – Communication, Navigation, Surveillance and Air Traffic Management
COTS – Commercial-Off-the-Shelf
CRS – Congressional Research Service
DOD – Department of Defense
DOT – Department of Transportation
FAA – Federal Aviation Administration
FAR – Federal Acquisition Regulations
FMS – Foreign Military Sales
ICAO – International Civil Aviation Organization
INAS – International Airspace System
MADM – Multi Attribute Decision Making
MCA – Military Certificate of Airworthiness
MCDA – Military Commercial Derivative Aircraft
MCO – Military Certification Office
MOA – Memorandum of Agreement
MTC – Military Type Certificate
OEM – Original Equipment Manufacturer
SME – Subject Matter Expert
TAA – Technical Airworthiness Authority
TSOA – Technical Standard Order Authorization
USAF – United States Air Force

Appendix B: Delphi Study Questionnaire One

Purpose:
The United States Air Force continually searches for ways to conserve materials and costs associated with our mission. A large portion of these costs are attributed to the acquisition of new aircraft. Air Force leaders can potentially reduce acquisition costs if they are able to take advantage of some of the benefits associated with utilizing aircraft that have already been developed by the commercial industry (commercial derivative aircraft or CDA). One potential benefit of utilizing CDA is related to the certification of the aircraft and its components by the Federal Aviation Administration (FAA). Currently, research is being conducted to help Air Force leaders determine if maintaining or achieving FAA certification of CDA or their associated repair processes is beneficial when compared to military certifications.

Participation:
Your participation in this study is COMPLETELY VOLUNTARY. This research is to be conducted by Captain Mike Low in fulfillment of a Master's degree program at the Air Force Institute of Technology (AFIT). This work is sponsored by the Air Force Materiel Command's Logistics Directorate.

Confidentiality:
This study will not collect personal identifiers or specific demographic information. Due to the nature of the electronic mail data collection process, the other study participants will know who you are but they will not know which comments are yours. At the end of the research, individual participant inputs will not be disclosed. You may withdraw from this study at any time without penalty; if you do, your data will not be used in the research. Your decision to participate or withdraw will not jeopardize your relationship with your department, the Air Force Institute of Technology, the Air Force, or the Department of Defense

Instructions:
You will be emailed a knowledge based questionnaire that will ask you to review a short set of criteria that Air Force leaders would potentially use to make decisions regarding the use of commercial derivative aircraft and certification processes. After reviewing the criteria, you will be asked to provide comments and recommendations regarding the validity of those criteria based on your current knowledge and experience. This study is simply a method of validating the criteria listed, so all comments are welcome, and participant names will NOT be used in the final project.

Over the course of the study, you will receive a series of emails (approximately 3-5 total). The first email will ask you to review the criteria and provide any comments or corrections you might have. Comments will be incorporated into the criteria and then resubmitted to participants until consensus is achieved. Please base all of your responses on your current level of knowledge and experience and make your comments as clear and concise as possible. With regard to the questions that will be asked, there is no "right" answer, so any comments you provide will be extremely helpful.

Contact Info:

If you have any questions, comments, or concerns about this study, please contact Capt Mike Low using the information below.

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Please review the following three statements below. Then, based on your current knowledge and experience, answer the five questions at the bottom of the page.

1. Regarding Air Force purchase of commercial derivative aircraft, the risk associated with purchasing aircraft near the ***end*** of the planned production run is due to primarily to the following factors:
    a. The length of time that a commercial supply chain infrastructure will remain in place is shorter when compared to purchases made at the beginning of the production run.
    b. The length of time that a systems engineering support will be available is shorter when compared to purchases made at the beginning of the production run.
2. Regarding Air Force purchase of commercial derivative aircraft, the risk associated with purchasing aircraft near the ***beginning*** of the planned production run is due to primarily to the following factors:
    a. The cost of each airframe is higher at the beginning of production when compared to later stages (due to production efficiencies achieved over time, manufacturer pricing changes, etc.)
    b. The level of quality of aircraft purchased is lower during initial stages of production when compared to later stages (due to employee experience gained over time, lessons learned, etc.)
    c. The production schedule is less stable at early stages of production and aircraft are less likely to be delivered according to schedule when compared to later stages (due to manufacturer scheduling and production experience increases, etc.)
3. Many of the benefits associated with maintaining or pursuing FAA certification of Air Force commercial derivative aircraft or repair processes can only be achieved when there is a large commercial fleet still in use by the commercial industry.

Question 1. Considering statement 1 above, would you say items 1a and 1b accurately identify the primary risks associated with Air Force purchases of commercial derivative aircraft made at the end of the scheduled production run? If not, please identify items you would add or remove.

Question 2. Considering statement 2 above, would you say items 2a, 2b, and 2c accurately identify the primary risks associated with Air Force purchases of commercial derivative aircraft made at the beginning of the planned production run? If not, please identify items you would add or remove.

Question 3. Considering statement 3 above, would you agree with the statement made regarding the benefits of FAA certification? If not, please identify why you disagree.

Question 4: Considering decisions Air Force leaders must make regarding whether or not to utilize commercial derivative aircraft, what additional comments or recommendations would you provide?

Question 5: Considering decisions Air Force leaders must make regarding whether or not to maintain or pursue FAA certification of commercial derivative aircraft and their associated repair processes, what additional comments or recommendations would you provide?

Appendix C: Delphi Study Questionnaire One Responses

<u>Question 1 Responses.</u>

1A. True. Using the KC-46 as example, the end of the production run is 2028. The AF will have 179 aircraft with projected life span of 40-50 yrs. Major commercial carriers will have replaced their 767 with newer types of aircraft by that time. Only the minor carriers, smaller foreign carriers, and cargo haulers will likely be using the 767 after 2025-2030. Most major supply chain vendors will stop supplying for the 767 due to diminishing market and need from the commercial side. The AF requirement for commercial supply support for 179 aircraft, while important to the AF, is a small requirement in the commercial world. 1B. Basically true. The AF will have to rely more on its own AF engineering and OEM engineering contract for long term support, similar to KC135 program.
Risk at the end of a production run may be associated with the supply and service infrastructure, if the production run is relatively small. However, for aircraft with a large commercial production run (e.g., B737 family of aircraft), I think this is statement does not apply as much. See answer to question 4 below. I feel statement 1b is not accurate. Regarding systems engineering support, FAA regulations (14 CFR 21 and 14 CFR 26) require that for aircraft that remain in service, the holder of a design approval (type certificate, amended type certificate, supplemental type certificate; e.g., Boeing) must supply the information necessary (not necessarily for free) for aircraft operators to operate and maintain those aircraft in an airworthy condition. Case in point is the Beech Starship. Only 53 aircraft were produced following certification due to various reasons. Beech determined that it would be cost prohibitive to support such a small fleet size and began to scrap and destroy the aircraft under its control. Beech attempted to acquire all of the privately owned aircraft, but was unsuccessful. Therefore, Beech is required to maintain and provide the instructions for continued airworthiness for this aircraft. (only 5 or 6 aircraft still in service) The design approval holder must also provide support for the continued airworthiness of and safety improvements for transport category airplanes with regard to electrical wiring interconnection systems maintenance, fuel tank flammability and damage tolerance data for repairs and alterations. This support may include performing assessments, developing design changes, developing revisions to Instructions for Continued Airworthiness (ICA), and making necessary documentation available to affected persons. Therefore, as long as an aircraft remains in service, some sort of systems engineering support should be available to a military operator of that aircraft.
Yes, 1a and 1b are accurate statements. Another factor to consider is the number of commercial aircraft in active service. For a highly successful aircraft, it is likely that supply chain and engineering support will last much longer than with an aircraft with low numbers in active commercial use.
Yes.
Yes, I agree with those statements.
I agree both statements 1a and 1bare correct.
Yes, I agree with 1a and 1b.

The availability of a supply chain is more dependent on the technology being used rather than where in the production life cycle an airplane is. Out of production aircraft still have up to a 20 year life cycle left in the commercial environment with both second and third tier airlines as well as cargo carriers. Engineering support is always available for a fee and isn't related to where in a production run an aircraft is. As long as there is an airplane model flying the owner of the type design is responsible for supporting it.

The response assumes production run is limited to an optimal run with profit maximization for the corporate entity. I would not agree with the position though I agree both your statements hold true. I would assert that the main issue with the late or end production run purchases of derivative aircraft is technical data cost and availability. This would include aircraft specification data and trend data for extension of Reliability and Maintainability (R&M) effort. Far too often the end of production run is assumed programmed improvement will no longer occur. Supply chain can be mitigated through Diminishing Manufacturing Sources (DMS) programs currently in place. Additionally, government engineering has the ability to pick up any required engineering actions, provided the data is made available.

1A. True. Using the KC-46 as example, the end of the production run is 2028. The AF will have 179 aircraft with projected life span of 40-50 yrs. Major commercial carriers will have replaced their 767 with newer types of aircraft by that time. Only the minor carriers, smaller foreign carriers, and cargo haulers will likely be using the 767 after 2025-2030. Most major supply chain vendors will stop supplying for the 767 due to diminishing market and need from the commercial side. The AF requirement for commercial supply support for 179 aircraft, while important to the AF is a small requirement in the commercial world.

1B. Basically true. The AF will have to rely more on its own AF engineering and OEM engineering contract for long term support, similar to KC135 program.

If you are inferring that part availability is a risk driver due to potential shortage of parts delivered near the end of a production run in a commercial environment then I would have to disagree. Part quality in an FAA environment is higher than our military variants and response time for a production run is quicker in the commercial world than our defense OEM's. Systems Engineering support does ramp up in the beginning of a production run and drop off over time as the product matures and more emphasis is placed on post-delivery support (for warranty) but I have not seen examples of where this is a driving risk factor for purchasing aircraft near the end of a production run . The risks that we have seen with purchasing near the end of a production run have to do with procuring a common configuration across the fleet you are ordering, and the stability of aircraft pricing and lead-time based on the amount of parts in the supplier system to support your order.

1A. Disagree: Although this may pose a slight risk, the supply chain infrastructure for commercial derivative aircraft usually remains robust due to the number of suppliers competing to provide materials and services. If the OEM (Original Equipment Manufacturer) were the only source for materials and services, this statement would be true only of the OERM decided not to support their product..

1B. Disagree: OEM's will invariable provide engineering support for a product beyond its production run. Additionally, Operators use internally engineering staff as well as DER (Designated Engineering Representatives) to provide engineering support rather than OEM engineering, mainly due to the fact the OEM Engineering and be cost prohibitive in the commercial world.

Agree.

Question 2 Responses.

I believe 2a and 2c to be fairly accurate. You may want to add another qualifier to item 2c. Since commercial production is highly market dependent, market volatility could adversely impact production, especially when the military is trying to piggy-back on a commercial production run for a small number of aircraft. Item 2b is not accurate. Production quality (at least with regard of airworthiness or safety of flight) is strictly controlled and regulated by the FAA; therefore, the level of quality of the first aircraft off of the production line should not be any less than that of the last production unit.

Yes, I would say the statements are generally true, risks are higher for a new production aircraft.

Yes.

I agree with 2a and 2c. I do not agree with 2b, reason being that level of quality is required to be maintained throughout the production stages. There are quality requirements for obtaining and maintaining FAA certification.

I agree 2a, 2b, 2c are correct.

Yes, I agree with 2a, 2b and 2c.

2A. Disagree. Buying a CDA that has been in production for a number of years should reduce the cost because all of the engineering and production line bugs have typically been resolved. While you always have continuous process improvement it doesn't provide huge gains in efficiencies for a mature production line. Manufacturing pricing will typically be lower in the beginning because of a "bulk" buy upfront and competition. Also pricing may increase in later years because of diminishing parts availability from commercial vendors as the commercial fleet downsizes.
2B. Disagree. For typical CDA production the production line is mature as the AF is procuring a proven CDA, not a new design. Most of the workforce is already experienced on the specific CDA line with proven training programs for new hires. While there is always room for improvement with any production line, the quick and easy "low hanging fruit" has already been picked when the line was new and immature. Process improvements to a mature line are harder to implement and likely do not carry the same dramatic levels of improvement.
2C. Disagree. Typical CDA the AF procures are already being produced and mature. Thus reduced risk to schedule. If the AF bought a new design that required a new or immature production line, then what you state would be true.

The cost of an airframe is based on the amortized business model developed. Generally speaking the value of an aircraft is higher in the beginning but not necessarily the price since "deals" are worked out to launch aircraft. Price usually goes up over time while value may decrease from a depreciation and marketplace perspective. Quality doesn't change over time since the quality standard is a constant. Certainly there might be reliability growth issues. First of a model aircraft obviously take longer since you have to do the initial testing. Production is done at risk while testing is going on. The delivery is dependent on FAA certification and not on efficiencies.

I would stress the three statements common in every manufacturing process. I agree the stated reasons, all conceptually within economy of scale, are concerns during early production. I offer the following addition information, production run aircraft are often between 70% to 90% of their maturation process. As the maturation process continues, less developmental support is

required allowing for staff reductions and additional process streamlining.

2A. Agree: The aircraft price at the beginning of a production run is higher due to NRE, labor efficiencies (learning curve), product maturity risk, OEM pricing strategies, etc. In the commercial world, the configuration stays more constant than in our DOD environment, thus the commercial pricing structure remains fairly even through the production runs and savings from efficiencies are not passed on to the consumer unless product demand falls off, volume discounts apply, or configuration change/model change are eminent (closeout sale).

2B. Disagree: In the FAA world, very little manufacturing process risk is undertaken in aircraft assembly. Technology maturity levels are very high for the most part so you won't see the same uptick in quality issues as compared to an F-22 for example.

2C. Agree: This is somewhat true about all manufacturers who have assembly issues in the early stages. Drivers here are likely due to differences in engineering estimates of assembly times, supplier deliver issues, equipment failures, etc. Production delay costs are more significant and painful for the commercial OEM's as they do not have the government support of additional funding to cover cost overruns. In later stages, it is generally true that schedules are far more predictable and represent a lower risk to the government.

The main risk we see purchasing up-front or for that matter at any time in a commercial environment is that the OEM owns the product until delivered – especially under a FAR 12 acquisition where you are basically buying an end item. Once the contract is signed, the configuration can be changed (i.e. a product enhancement) without your knowledge or consent. We are dealing with a possible order this year for 15 Cessna 208 Caravans where the fleet might have 2 configurations based on a planned production model changeover in the middle of our order. For maintenance reasons, a mixed fleet drives cost for training, equipment, and part ordering/stocking 2 configurations. Engineering changes – which are commonplace in DOD OEM's during a production run, are difficult or impossible to accomplish after the order has been placed. In almost every case, we end up performing post-delivery mods after receiving the green aircraft which adds cost due to disassembly/rework of the aircraft from the original assembly. The recently awarded KC-46 will be an exception to this model as Boeing has established a unique assembly line to incorporate Military products as the aircraft is being built negating the post production modification standard saving time and cost.

2A. Partially Agree: The "Catalog Price" at the beginning of production is based on planned production costs, anticipated market demand and parametric comparisons of capabilities of like market equipment. When the consumer demand wanes, or if a customer is identified as 'preferred" by the OEM due to large future orders or standing preferred customer status, substantial cost reductions and/ or concessions are common. Although production efficiencies are realized as the production line and processes mature, these cost savings are seldom reflected in the "Catalog Price".

2B. Disagree: Manufacturing processes for commercial derivative aircraft are, for the most part, mature and routine. Unless the aircraft is being provided by a "Start Up" manufacturer, the risk is extremely low. It is doubtful that a startup manufacturer would make it through risk matrix or source selection process. The risk to the Government would be too great.

2C. Partially Agree: As previously stated, If the OEM were a startup manufacturer, this might hold true. However since most commercial derivative aircraft are not start up's, the production processes are already mature and in place. Material shortages may pose a slight risk, however this would be the exception and not the rule.

Agree.

2A. Disagree. Buying a CDA that has been in production for a number of years should reduce the cost because all of the engineering and production line bugs have typically been resolved. While you always have continuous process improvement it doesn't provide huge gains in efficiencies for a mature production line. Manufacturing pricing will typically be lower in the beginning because of a "bulk" buy upfront and competition. Also pricing may increase in later years because of diminishing parts availability from commercial vendors as the commercial fleet downsizes.
2B. Disagree. For typical CDA production the production line is mature as the AF is procuring a proven CDA, not a new design. Most of the workforce is already experienced on the specific CDA line with proven training programs for new hires. While there is always room for improvement with any production line, the quick and easy "low hanging fruit" has already been picked when the line was new and immature. Process improvements to a mature line are harder to implement and likely do not carry the same dramatic levels of improvement.
2C. Disagree. Typical CDA the AF procures are already being produced and mature. Thus reduced risk to schedule. If the AF bought a new design that required a new or immature production line, then what you state would be true.

Question 3 Responses.

Disagree. First, the AF would lose the intangible benefits of the FAA quality and safety oversight of the CDA weapon system. The FAA programs equate to the ISO 9000 and AS 9110 standards that are recognized and accepted industry wide as the standard or "best practice". It gives the AF another layer of safety and quality oversight from the aviation experts (FAA) that cannot be achieved without them. Next the AF MUST determine what they want to do with the CDA upon retirement from the AF. Do they want to sell the aircraft to commercial operators or just salvage them? If the decision is to sell them to commercial operators, then FAA airworthiness certification really needs to be maintained throughout the life cycle of the aircraft. If not, the AF must review the maintenance records for the entire life of the aircraft and prove to the FAA that all maintenance, mods, repairs, parts, ADs/SBs, were accomplished correctly to the satisfaction of the FAA. This is a time consuming process and must be done for every tail number, not just for a type of aircraft. Will this apply to aircraft like the KC-46? That decision hasn't been made yet. But it definitely applies to aircraft like the C-21, C-20, and T-43 that are reaching the end of their life cycle in the AF and are highly desirable to commercial operators. Lastly the fleet size really only impacts the availability of approved commercial parts. As the commercial fleet decreases in size the number of parts vendors decrease as well. But that's not to say approved FAA parts will not be available. The AF can be certified by the FAA to produce a new part and repair them as well (either Part 121 or Part 145). This effort is not complex, just a "new" way of doing business.

I disagree with the statement in that it implies that the only advantage of FAA certification of commercial derivative aircraft is in regard to sustainment. This devalues the potential benefits provided during the EMD phase of the program. Obtaining FAA certification of commercial derivative aircraft takes advantage of the commercial processes already in place and reduces the USAF manpower required to certify the aircraft by leveraging off of the FAA. AFI 62-601 states that FAA type certification is the preferred method of certifying airworthiness of USAF operated CDA.

There are many issues to work through for the military to reap the maximum benefits of CDA's besides just having a large commercial fleet still in use. Commercial repair and parts pooling procedures are much different than Air Force procedures. Reparable parts in the commercial sector need to be tagged with an 8130-3 Airworthiness tag, the AF ALC's presently cannot do this. Also, FAA traceability and segregation requirements for consumable parts are different.

Yes.

Disagree. Yes, it is true that there are more opportunities for savings with a robust commercial industry, but there are savings that will be realized through just maintaining FAA certification.

Disagree. Your statement might be true if the Government was going to rely solely on the contractor for sustainment of the system acquired. Also, I'm not sure AFI 62-6 allows this flexibility. See my response to Questions 4 and 5.

There seems to be a benefit if you are in an open parts pool, but in the case of a closed parts pool, I do not see the benefit of keeping the LIKE FAA certification.

The benefit of FAA certification based on fleet size is a supply chain perspective. The real benefit is use of existing data and licensing rather than owning data. To recreate data for unlimited rites is a very expensive proposition since it will likely need to be reverse engineered. Maintaining commonality with the commercial variants allows for synergies and economies of scale that would not normally be available for a military aircraft.

The size of the available fleet is important, but far more important is the ability to access the desired shared resources. The commercial parts pool and other scale issues are contractual arrangements where all participating partners have agreed to a specific obligations. The participating military force structure being supported by the common pool resources has not been accomplished to date. This collaboration has significant risk associated. It would be most embarrassing to have the parts pool partners exercise political options and keep one of our aircraft from completing its combat mission by withholding parts. This is conjecture, though throughout our own history the political exploits of withholding resources to achieve our objectives has been exercised. This is of course a two way street.

Disagree. First, the AF would lose the intangible benefits of the FAA quality and safety oversight of the CDA weapon system. The FAA programs equate to the ISO 9000 and AS 9110 standards that are recognized and accepted industry wide as the standard or "best practice". It gives the AF another layer of safety and quality oversight from the aviation experts (FAA) that cannot be achieved without them.

Next the AF MUST determine what they want to do with the CDA upon retirement from the AF. Do they want to sell the aircraft to commercial operators or just salvage them? If the decision is to sell them to commercial operators, then FAA airworthiness certification really needs to be maintained throughout the life cycle of the aircraft. If not, the AF must review the maintenance records for the entire life of the aircraft and prove to the FAA that all maintenance, mods, repairs, parts, ADs/SBs, were accomplished correctly to the satisfaction of the FAA. This is a time consuming process and must be done for every tail number, not just for a type of aircraft. Will this apply to aircraft like the KC-46? That decision hasn't been made yet. But it definitely applies to aircraft like the C-21, C-20, and T-43 that are reaching the end of their life cycle in the AF and are highly desirable to commercial operators.

Lastly the fleet size really only impacts the availability of approved commercial parts. As the commercial fleet decreases in size the number of parts vendors decrease as well. But that's not to say approved FAA parts will not be available. The AF can be certified by the FAA to produce

a new part and repair them as well (either Part 121 or Part 145). This effort is not complex, just a "new" way of doing business.

Disagree: The FAA provides continuous monitoring of certification adherence well after delivery of the aircraft. Maintenance & repair processes are monitored regardless of the fleet size. If the equipment has an FAA certification, the FAA is mandated to provide oversight and the holder is required to remain in compliance. We would see benefits from a larger fleet size post-delivery in more repair centers around the country/world for service and a larger parts pool for spares.

Disagree: The FAA provides continuous monitoring of certification adherence as well as enforcement of compliance with approved maintenance & repair processes regardless of the fleet size or type of aircraft. If the equipment has an FAA certification, the FAA is mandated to provide oversight and the holder is required to remain in compliance.

Agree. A large commercial fleet enhances the ability for increased maintenance, supply and engineering support not only in the US but worldwide.

Question 4 Responses.

Number 1 is the total cost to field a new weapon system based on a military unique design (B-2) or a design based on a CDA (KC-46). The key is to restrict changes to a CDA design to a TRUE requirements for military specific missions...not just "neat to have" stuff. The MC-12 program is an outstanding example of how successful this can be! Also there is the potential to reduce the amount of spares bought up front due to "parts pooling" agreements the AF has with commercial carriers. This can potentially save BILLIONS of taxpayer dollars and definitely worth the work to establish these agreements.

Much like automobiles, I feel that the number of aircraft produced and the number of different commercial operators of that aircraft have more of an influence on supply chain infrastructure, than when during the production run the aircraft are purchased. The larger the overall production run, the greater the availability of services and supplies. Case in point is the B737, first delivered in the late 1960's. With almost 7,000 aircraft delivered (>4500 still in service) and ~2200 on order, and operated all over the world by over 500 airlines (8 operators within the USA alone) with a well-established supply and repair infrastructure that will be in place for years to come. There are still approximately 380 B737-200 (first model delivered of the B737 family) still in service. With such a large production run spanning over approx. 45 years, it is inherent that early adoption of the B737 provided benefits regarding the length of time that supplies and services would be available to those early operators, such as Southwest Airlines. Purchasing at the end of a planned production run can reduce risk in that it allows better insight into the size of the commercial supply chain and repair infrastructure to allow a better assessment as to the potential benefits available to the government purchaser.

Air Force leaders must realize that there is benefit to using CDA's on the developmental and production side, but differences in logistics, maintenance, and receiving inspection procedures between the Air Force and FAA standards, make many touted benefits on the sustainment side, such as parts pooling, difficult to achieve.

Must consider AF goals as to whether to maintain organically or with contractor support. Commercial Derivative Aircraft (CDA) rely on a commercial parts pool and the necessary provisioning data to transition required parts into the AF supply system for full organic support

may not always be available. We are experiencing this very issue on the KC-46. In the long term when the AF becomes the only user of this aircraft it is imperative we have all necessary data to provision and possibly reverse engineer parts for repair when they no longer are available for procurement through commercial sources due to obsolescence.

I think it is very beneficial to pursue utilizing commercial derivative aircraft. There are a lot of benefits such as COTS, supply chain management, large parts pool, and proven technology.

I'm not sure where your next survey/questions will be directed, but I think it is very important additional information is considered in each of the statements/questions above; we are not given the full context of the program that senior leaders will be making their decision in. For example, what is the long-term sustainment strategy after the CDA are acquired? If the government will be utilizing CLS for life, considering if the CDA is in the beginning/end of production may/may not be a primary consideration (contractor has to support the aircraft regardless). However, if after acquiring the CDA with the intent is to transition to a fully organic (government maintained) posture, I believe data rights (and cost) far exceed considering where the production cycle is.

I think it is a good idea for savings. I just don't see the savings maintaining it as a commercial A/C.

The real inefficiencies are driven by multiple contracts for the same thing rather than increasing the buying power of the DOD by combining requirements or using IDIQ contracts to standardize the business model used by the services. Buying the same things differently is very costly. Consideration should also be given to using commercial airlines to buy the basic aircraft and competing the modifications. That way you would just be a part of a larger airline purchase for the basic airframe and take better advantage of commercial business practices.

Number 1 is the total cost to field a new weapon system based on a military unique design (B-2) or a design based on a CDA (KC-46). The key is to restrict changes to a CDA design to a TRUE requirements for military specific missions...not just "neat to have" stuff. The MC-12 program is an outstanding example of how successful this can be! Also there is the potential to reduce the amount of spares bought up front due to "parts pooling" agreements the AF has with commercial carriers. This can potentially save BILLIONS of taxpayer dollars and definitely worth the work to establish these agreements.

The leadership recognized economies of scale have yet to be codified. There is significant risk with tying ourselves to an commercial aircraft for long term sustainment and support. In the forefront, there is the tie back to the manufacture for engineering support without recourse. This means unless the government provides significant investment, items previously captured in avoidance or savings, we are subject to the technology refresh cycles of industry. While partnering with industry will provide some small measure of influence, when it comes time produce a new aircraft industry will do it and phase out what may be our most important asset militarily. As an example, we see this process repeated every 3 to 5 years by Microsoft, other software manufacturer's, the auto industry and literally every other no commodity item.
To summarize, industry operates with profit motivation. The aviation market is not within our control and we can only provide a limited stakeholder interaction. We are not the majority vote and will be influenced in ways we cannot for see at this time.

See answer above to questions 1, 2 and 3.

Here are few additional reasons for utilizing a commercial derivative aircraft; lower development cost, reduced testing schedule, quicker delivery to the field and lower upfront logistics cost by

tapping into existing commercial process and products. Utilization of commercial manufacturing and quality assurance oversight is also available. Safety of the aircraft is increased by using the existing civil airworthiness certificate already issued to the baseline aircraft.

Question 5 Responses.

I've attached a draft white paper that provides a comprehensive look at the issue of maintaining commercial derivative aircraft (CDA) airworthiness. The paper is authored by Mr. Jim Warren, a support contractor in our office supporting us in the area of airworthiness. Jim is an ASC/EN civilian retiree who has worked many CDA programs. Although the white paper title infers that it is regarding the KC-46, the information applies to other CDA. Although the information in the paper is considered to be accurate, please treat the paper as a draft. I would recommend that you contact Jim at 51589 for the status of finalization of the paper.

Pursue FAA certification or equivalency for the Air Force ALC's, and ensure Air Force Supply chain policies and procedures can accommodate the management of FAA parts.

FAA certification adds another layer of safety and quality oversight that should not be ignored. There have been deadly crashes (T-3, C-21, etc.) in CDA that would not have likely happened if the AF was truly committed to maintaining and operating these aircraft IAW FAA standards. FAA certification also aligns the AF with industry MRO leaders with a standard that is recognized worldwide. This opens doors to better communication/relationships with commercial providers, increased partnering possibilities with OEM's, increased credibility within industry, enhanced mechanic certifications (A&P, etc.), and improved safety and quality programs. I've already mentioned how maintaining FAA airworthiness would eliminate the lengthy and costly audit for each tail number that the AF wants to sell to the public. Also the cost to certify the 76 MXW FAA Part 145 repair station was less than $20,000...not the millions you hear mentioned by others.

Must consider addressing 3 key process areas: Engineering, Maintenance, and Supply. Engineering- Must have manpower to support dual certifications (FAA and Military) Organic and Depot Level Maintenance-Must have FAA memo recognizing AF O-level maintenance as equivalent. Depots must obtain and sustain FAR Part 145 Certification. Retail/Wholesale Supply-Management and visibility of certified FAA parts—FAA certified parts require separate NSNs. Also must have control and constant visibility of FAA certified parts. AF data systems/processes not currently set up to manage FAA certified parts.

Staying within the FAA system allows us to use all the authorized parts manufacturers/repair licensees, etc. as we see fit. If we were to not do that then they couldn't use their licenses on anything for us and we would have to establish separate contracts and separate contract administration functions. There is also comfort in numbers. When analyzing the impact of design flaws, accidents, etc. making decisions on the basis of our data alone would be flawed. Then there is also the additional cost of doing anything unique or as a customer of one. A lot of the "savings" are ion reality cost avoidance which never gets recognized or analyzed. It all traces back to the design data and the approvals.

I believe CDA can save the Government development funds, but as far as FAA certification we must fully understand the implications FAA certification has on the enterprise. My experience has been the Government may not be as well suited to retaining this certification and realizing the benefits expected. Commercial parts pools, data rights, commercial tech orders, FAR Part

145 certification, FAA "equivalency," all have proven challenging on KC-46. This doesn't even speak to parts traceability, accountability, IT system interfacing (G081/CEMS) that are all challenges yet to come. Recommend you devise a way that accounts for the moving parts in each program. The tool might be as simple as a decision tree that guides AOs or PMs in teeing up topics for decision makers through common considerations lumped together in categories. For example, to use your earlier case, FAA certification retention. What is the sustainment strategy (CLS, organic, PPP)? Are Core, 50/50 impacts expected? Are IT systems capable of supporting the desired approach? Is funding available to modify the IT systems if needed? Etc...

I do not see the benefits of maintaining a FAA certified A/C with a closed parts pool. I can see the benefit of buying a FAA certified A/C for the cost savings, but not maintaining a like FAA certification.

The USAF and DOD need to take a close look at the differences between the airline industry and their practices and align them better in order to take maximum advantage of the commercial business model . It has been proven to be more efficient and less costly. The USAF can no longer afford unique processes unless specifically justified. The “we have always done it this way” argument doesn’t hold water any longer.

The comments for repair process and parts are no different than question 4. Once again, the risk is high we will be captured in the tech refresh cycles and be forced to recapitalize or replace usable aircraft due to industry influence. But this is an issue for tomorrow and it is unlikely the current decision makers will concern themselves past the a 15 year forecast.

For design purposes, an FAA type certificate always benefits the Air Force for airworthiness reasons alone* (all of our aircraft are Military Certified for use), however the 50/50 rule for maintenance will always be a concern with determining who maintains the aircraft in a cost effective manner. Does it make sense to duplicate or compete with private industry for maintenance and/or repair of commercial aircraft to comply with the law – even for small fleet sizes?

* Savings derived from not duplicating engineering analysis of design on the Military side

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Maintaining FAA certification is beneficial as well. I've listed a few of the advantages below. Configuration control. The FAA regulates this process and approves all changes. This keeps modifications to a standard configuration. FAA standards are recognized internationally. Safety operation of the aircraft and airworthiness standards issued by the FAA are accepted worldwide providing continuity for global operation. Use of parts from the commercial parts pool provides a larger source for replacement components without having to increase sparing levels. FAA database used to track part failures throughout the commercial fleet. This information is used to track failure statistics that may indicate changes in failure rates, repair vendor quality problems or possible design related issues. Safety of commercial derivative aircraft is enhanced by utilizing the commercial fleet’s access to technology and experience. Provides a greater base to access safety related topics that may surface within the commercial fleet.

FAA certification adds another layer of safety and quality oversight that should not be ignored. There have been deadly crashes (T-3, C-21, etc.) in CDA that would not have likely happened if the AF was truly committed to maintaining and operating these aircraft IAW FAA standards. FAA certification also aligns the AF with industry MRO leaders with a standard that is recognized worldwide. This opens doors to better communication/relationships with commercial providers, increased partnering possibilities with OEM's, increased credibility within industry, enhanced mechanic certifications (A&P, etc.), and improved safety and quality programs. I’ve already mentioned how maintaining FAA airworthiness would eliminate the lengthy and costly

audit for each tail number that the AF wants to sell to the public. Also the cost to certify the 76 MXW FAA Part 145 repair station was less than $20,000...not the millions you hear mentioned by others.

Appendix D: Delphi Study Questionnaire One Revised Statements

Revised Questionnaire Statements

Two of the statements from the original questionnaire were modified based on inputs received. Modifications are *italicized*.

Please review the following two statements below. Then, based on your current knowledge and experience, identify whether you agree or disagree. Also, please identify any items you would add or remove.

1. Regarding Air Force purchase of commercial derivative aircraft, one of the risks associated with purchasing aircraft near the beginning of the planned production run is that the level of quality of aircraft purchased *can be* lower during initial stages of production when compared to later stages (due to employee experience gained over time, lessons learned, etc.) *However, when well-established manufacturers and proven (mature) technology are used, quality is fairly constant throughout the production process and this risk is minimal.*

2. Many of the ***sustainment related*** benefits associated with maintaining or pursuing FAA certification of Air Force commercial derivative aircraft or repair processes can only be achieved when there is a large commercial fleet still in use by the commercial industry (benefits might include a larger parts pool or an increased number of repair centers, for example). *However, regardless of fleet size, additional benefits can be achieved through the use of existing FAA data, certifications, and processes. There are also benefits associated with additional FAA oversight of regulation compliance and maintenance practices.*

Appendix E: Delphi Study Questionnaire Two

Introduction:
Based on responses received from participants in this study (as well as additional research), several key benefits to maintaining FAA certification on military commercial derivative aircraft (MCDA) were identified and are listed below (in no particular order). This list is not meant to be all-inclusive, but only to identify a majority of the most beneficial attributes associated with maintaining FAA certification (beneficial with regard to potential cost savings, improved safety, etc). The *costs* associated with maintaining FAA certification are not included in this portion of the study. The questions below should be answered based on your current level of knowledge and experience.

Instructions:
Please divide 100 points among the attributes listed below based on your estimation of their level of impact. For example, if you feel that being able to participate in the commercial parts pool for common commercial parts is the biggest benefit that comes from maintaining FAA certification of MCDA, then that attribute should receive the most points relative to the other attributes. You may also feel that some attributes provide no benefit at all, in which case you would assign zero points. Since these attributes were all identified as being potentially beneficial, no negative numbers should be used. Fractions are allowed, but **the total of all points combined must equal 100, no more and no less.**

Attribute	**Score**
Participation in the commercial parts (spares) pool	
Access to established commercial maintenance support and infrastructure	
Access to an established commercial supply chain	
Use of existing manuals, repair/failure data, and technical data	
Use of existing FAA approved processes (Service Bulletin and Airworthiness Directive processes, repair processes, etc.)	
Improved control and tracking of aircraft configuration data	
Ability to participate in cross-servicing with European Aviation Safety Agency (EASA) and FAA fleets	
Ability to sell demilitarized MCDA back to commercial market	
Reduced need to acquire proprietary OEM design data or flight test data (this could also be considered the benefit associated with a reduced likelihood that "reverse engineering" would have to take place, assuming a continuing OEM relationship is maintained)	
Improved safety due to increased FAA oversight	
Total	**100**

If you feel the list is missing a substantial benefit, please try to account for it within one of the existing attributes (and annotate the table accordingly), or list it below along with the score you would assign (remember that your combined total must equal exactly 100).

Instructions:
Concerning the same potential benefits from the first part of the questionnaire, please consider how the impact of those benefits might change over the life of the fleet. Fill in the columns below by referencing the figures on the following page. Figures 1 through 9 on the following page represent varying behaviors with respect to time. The life cycle timeline at the top of the following page assigns numbers to various life cycle stages. An example is provided below.

Example:
If you feel that the *benefit* associated with participation in the commercial parts pool would be fairly constant once the fleet reached mid-production, but then reduce dramatically as the commercial fleet began to retire, you would choose Figure 4 as the most appropriate behavior graph and enter that figure number in the chart below.

Next, utilizing the life cycle timeline at the top of the page, identify which numbers on the timeline correspond to points A and B in the figure. In this example, you would choose life cycle number 2 (mid production) for point A and lifecycle number 5 (commercial retirement) for point B, and enter those numbers in the appropriate columns below. If you're unsure of which life cycle numbers to use, leave those columns blank.

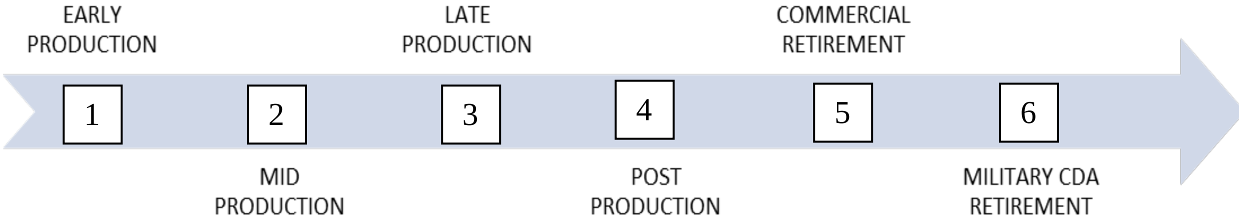
Attribute	**Figure (1 - 9)**	**Life Cycle # for Point A**	**Life Cycle # for Point B**
Participation in the commercial parts pool	4	2	5

Note: *You only need to enter life cycle numbers for Figures 1-6, because Figures 7-9 do not contain points A and B.*

Fill in the columns below based on your best *estimation* of how these benefits might change over time.

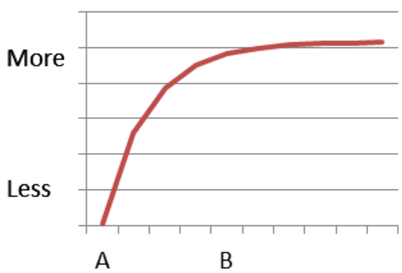
Attribute	**Figure (1 - 9)**	**Life Cycle # for Point A**	**Life Cycle # for Point B**
Participation in the commercial parts (spares) pool			
Access to established commercial maintenance support and infrastructure			
Access to an established commercial supply chain			
Use of existing manuals, repair/failure data, and technical data			
Use of existing FAA approved processes (Service Bulletin and Airworthiness Directive processes, repair processes, etc.)			
Improved control and tracking of aircraft configuration data			
Ability to participate in cross-servicing with European Aviation Safety Agency (EASA) and FAA fleets			
Ability to sell demilitarized MCDA back to commercial market			
Reduced need to acquire proprietary OEM design data or flight test data (this could also be considered the benefit associated with a reduced likelihood that "reverse engineering" would have to take place, assuming a continuing OEM relationship is maintained)			
Improved safety due to increased FAA oversight			

Fleet Life Cycle Timeline



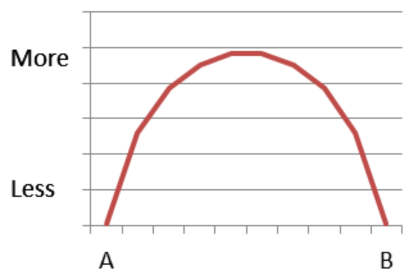
Behavior Over Time (Figures 1 through 9)

FIGURE 1



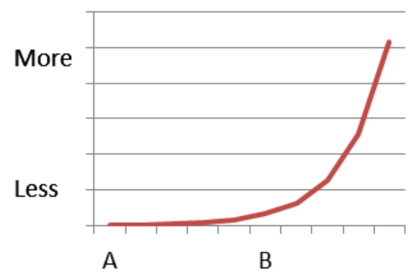
Increases dramatically from point A to point B and then levels off

FIGURE 2



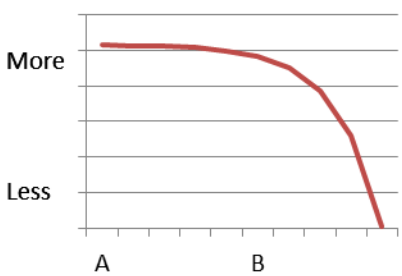
Increases from point A to a peak and then decreases to point B

FIGURE 3



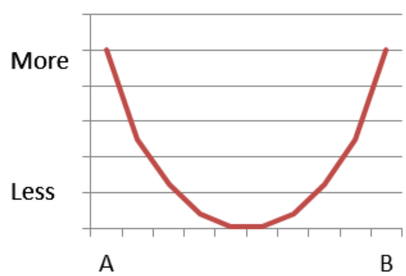
Fairly constant between points A and B, then increases dramatically

FIGURE 4



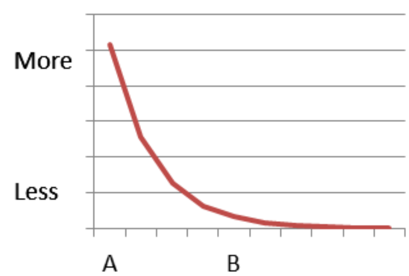
Fairly constant between points A and B, then decreases dramatically

FIGURE 5



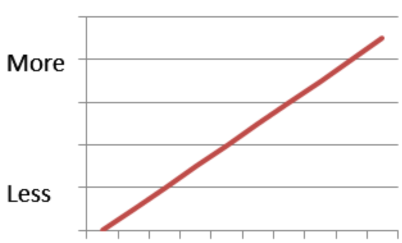
Decreases from point A to a low and then increases to point B

FIGURE 6



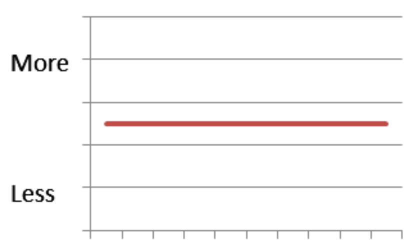
Decreases dramatically from point A to point B and then levels off

FIGURE 7



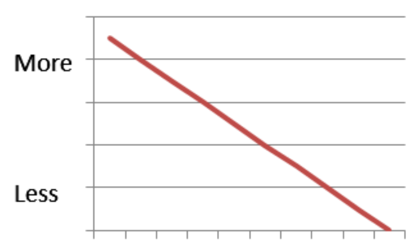
Fairly constant rate of increase through all points

FIGURE 8



Fairly constant rate through all points (little or no change)

FIGURE 9



Fairly constant rate of decrease through all points

Appendix F. Attribute Weights and Averages

	1	2	3	4	5	6	7	8	9	10	Total	Mean
Attribute	**Score**	**Score**	**Score**	**Score**	**Score**	**Score**	**Score**	**Score**	**Score**	**Score**		
Participation in the commercial parts (spares) pool	15	20	35	20	20	40	20	15	20	5	210	21.00
Access to established commercial maintenance support and infrastructure	10	10	10	5	10	0	2	10	5	5	67	6.70
Access to an established commercial supply chain	10	15	20	18	20	10	12	10	20	20	155	15.50
Use of existing manuals, repair/failure data, and technical data	10	15	10	6	10	15	9	10	10	30	125	12.50
Use of existing FAA approved processes (Service Bulletin and Airworthiness Directive processes, repair processes, etc.)	15	15	5	7	5	5	8	15	9	30	114	11.40
Improved control and tracking of aircraft configuration data	15	10	5	12	10	0	5	5	1	1	64	6.40
Ability to participate in cross-servicing with European Aviation Safety Agency (EASA) and FAA fleets	10	0	1	15	5	0	3	5	2	3	44	4.40
Ability to sell demilitarized MCDA back to commercial market	5	5	4	9	10	25	1	5	1	1	66	6.60
Reduced need to acquire proprietary OEM design data or flight test data (this could also be considered the benefit associated with a reduced likelihood that "reverse engineering" would have to take place, assuming a continuing OEM relationship is maintained)	5	5	5	8	5	0	25	0	30	0	83	8.30
Improved safety due to increased FAA oversight	5	5	5	0	5	5	15	25	2	5	72	7.20
Total	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	1000	100.00

Appendix G. Attribute Behavior Curves

	1	2	3	4	5	6	7	8	9	10
Attribute	**Figure (1 - 9)**	**Figure (1 - 9)**	**Figure (1 - 9)**	**Figure (1 - 9)**	**Figure (1 - 9)**	**Figure (1 - 9)**	**Figure (1 - 9)**	**Figure (1 - 9)**	**Figure (1 - 9)**	**Figure (1 - 9)**
Participation in the commercial parts (spares) pool	4	4	4	6	4	4	4	1	4	4
Access to established commercial maintenance support and infrastructure	4	4	8	6	8	4	2	2	4	5
Access to an established commercial supply chain	4	4	4	4	4	4	4	3	1	4
Use of existing manuals, repair/failure data, and technical data	6	4	8	8	8	8	1	3	8	9
Use of existing FAA approved processes (Service Bulletin and Airworthiness Directive processes, repair processes, etc.)	8	2	4	8	8	8	1	1	8	8
Improved control and tracking of aircraft configuration data	4	2	8	6	8	8	1	7	8	9
Ability to participate in cross-servicing with European Aviation Safety Agency (EASA) and FAA fleets	6	9	8	4	8		2		8	8
Ability to sell demilitarized MCDA back to commercial market	3	3	6	6	4	4	8	2	6	8
Reduced need to acquire proprietary OEM design data or flight test data (this could also be considered the benefit associated with a reduced likelihood that “reverse engineering” would have to take place, assuming a continuing OEM relationship is maintained)	6	3	6	4	1	9	3	4	4	3
Improved safety due to increased FAA oversight	8	8	8	8	8	8	1	4	8	8

Appendix H. Attribute Behavior Curve Point A Identification

	1	2	3	4	5	6	7	8	9	10
Attribute	**Life Cycle # for Point A**	**Life Cycle # for Point A**	**Life Cycle # for Point A**	**Life Cycle # for Point A**	**Life Cycle # for Point A**	**Life Cycle # for Point A**	**Life Cycle # for Point A**	**Life Cycle # for Point A**	**Life Cycle # for Point A**	**Life Cycle # for Point A**
Participation in the commercial parts (spares) pool	2	1	2	1	2	2	1	4	1	2
Access to established commercial maintenance support and infrastructure	2	4		1		2	1	4	1	1
Access to an established commercial supply chain	1	1	2	2	1	2	2	2	1	1
Use of existing manuals, repair/failure data, and technical data	1	1					1	1		
Use of existing FAA approved processes (Service Bulletin and Airworthiness Directive processes, repair processes, etc.)		1	1				1	4		
Improved control and tracking of aircraft configuration data	1	1		1			1	1		
Ability to participate in cross-servicing with European Aviation Safety Agency (EASA) and FAA fleets	1			2			2			
Ability to sell demilitarized MCDA back to commercial market	1	5	4	4	3	1		5	1	
Reduced need to acquire proprietary OEM design data or flight test data (this could also be considered the benefit associated with a reduced likelihood that “reverse engineering” would have to take place, assuming a continuing OEM relationship is maintained)	1	4	1	1	1		1	1	1	1
Improved safety due to increased FAA oversight							1	1		

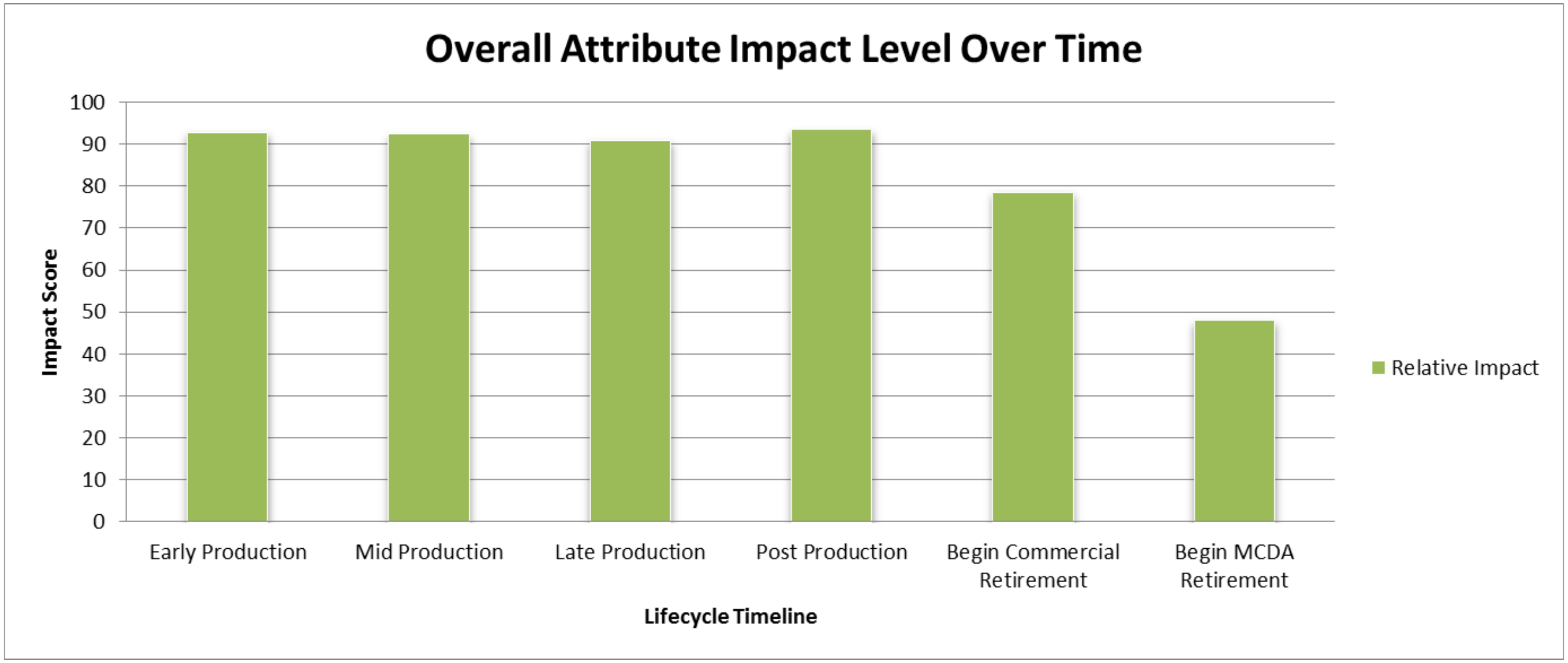
Appendix I. Attribute Behavior Curve Point B Identification

	1	2	3	4	5	6	7	8	9	10
Attribute	**Life Cycle # for Point B**	**Life Cycle # for Point B**	**Life Cycle # for Point B**	**Life Cycle # for Point B**	**Life Cycle # for Point B**	**Life Cycle # for Point B**	**Life Cycle # for Point B**	**Life Cycle # for Point B**	**Life Cycle # for Point B**	**Life Cycle # for Point B**
Participation in the commercial parts (spares) pool	5	5	4	5	5	5	5	5	5	5
Access to established commercial maintenance support and infrastructure	5	5		5		5	5	5	6	6
Access to an established commercial supply chain	5	5	4	5	5	5	5	5	2	5
Use of existing manuals, repair/failure data, and technical data	4	5					2	5		
Use of existing FAA approved processes (Service Bulletin and Airworthiness Directive processes, repair processes, etc.)		6	4				4	5		
Improved control and tracking of aircraft configuration data	6	5		5			6	5		
Ability to participate in cross-servicing with European Aviation Safety Agency (EASA) and FAA fleets	5			5			5			
Ability to sell demilitarized MCDA back to commercial market	5	6	6	5	6	5		6	5	
Reduced need to acquire proprietary OEM design data or flight test data (this could also be considered the benefit associated with a reduced likelihood that "reverse engineering" would have to take place, assuming a continuing OEM relationship is maintained)	5	5	3	4	4		1	6	6	3
Improved safety due to increased FAA oversight							6	6		

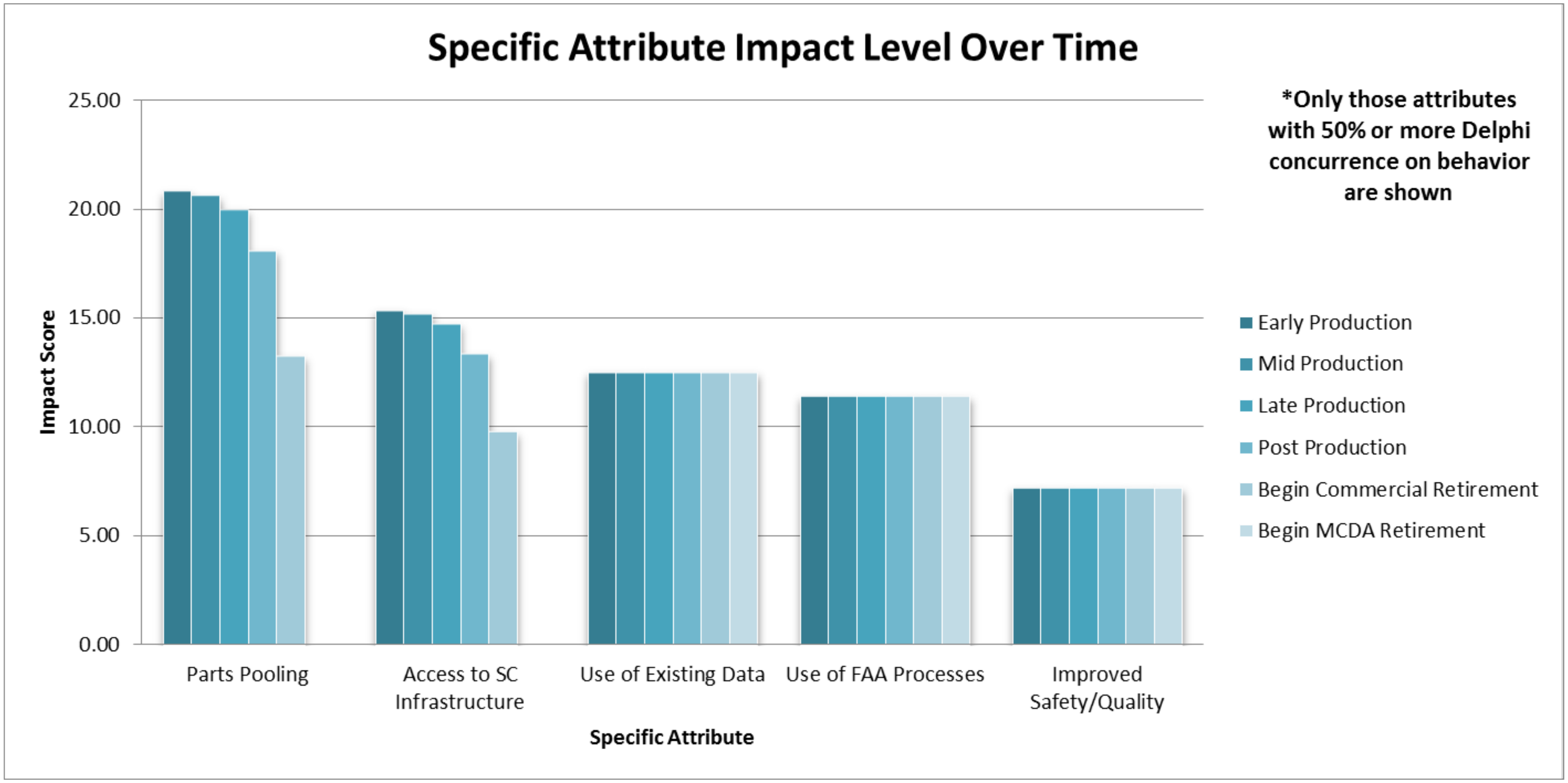
Appendix J. Decision Support Tool

		MCDA Fleet Life Cycle Stages											
		Early Production		Mid Production		Late Production		Post Production		Begin Commercial Retirement		Begin MCDA Retirement	
FAA Certification Decision Criteria (Attributes)	Attribute Weight	Impact Level	Impact Score	Impact Level	Impact Score	Impact Level	Impact Score	Impact Level	Impact Score	Impact Level	Impact Score	Impact Level	Impact Score
Parts Pooling	21.0	0.99	20.79	0.98	20.58	0.95	19.95	0.86	18.06	0.63	13.23	0	0.00
Access to SC Infrastructure	15.5	0.99	15.35	0.98	15.19	0.95	14.73	0.86	13.33	0.63	9.77	0	0.00
Use of Existing Data	12.5	1	12.50	1	12.50	1	12.50	1	12.50	1	12.50	1	12.50
Use of FAA Processes	11.4	1	11.40	1	11.40	1	11.40	1	11.40	1	11.40	1	11.40
Access to Proprietary Data	8.3	1	8.30	0.99	8.22	0.98	8.13	0.95	7.89	0.86	7.14	0.63	5.23
Improved Safety/Quality	7.2	1	7.20	1	7.20	1	7.20	1	7.20	1	7.20	1	7.20
Maintenance Support	6.7	0.99	6.63	0.98	6.57	0.95	6.37	0.86	5.76	0.63	4.22	0	0.00
Commercial Sell Back	6.6	0	0.00	0	0.00	0	0.00	1	6.60	0.37	2.44	0.14	0.92
Improved Config Control	6.4	1	6.40	1	6.40	1	6.40	1	6.40	1	6.40	1	6.40
FAA/EASA Cross Servicing	4.4	1	4.40	1	4.40	1	4.40	1	4.40	1	4.40	1	4.40
Totals	100		92.97		92.45		91.07		93.54		78.70		48.05

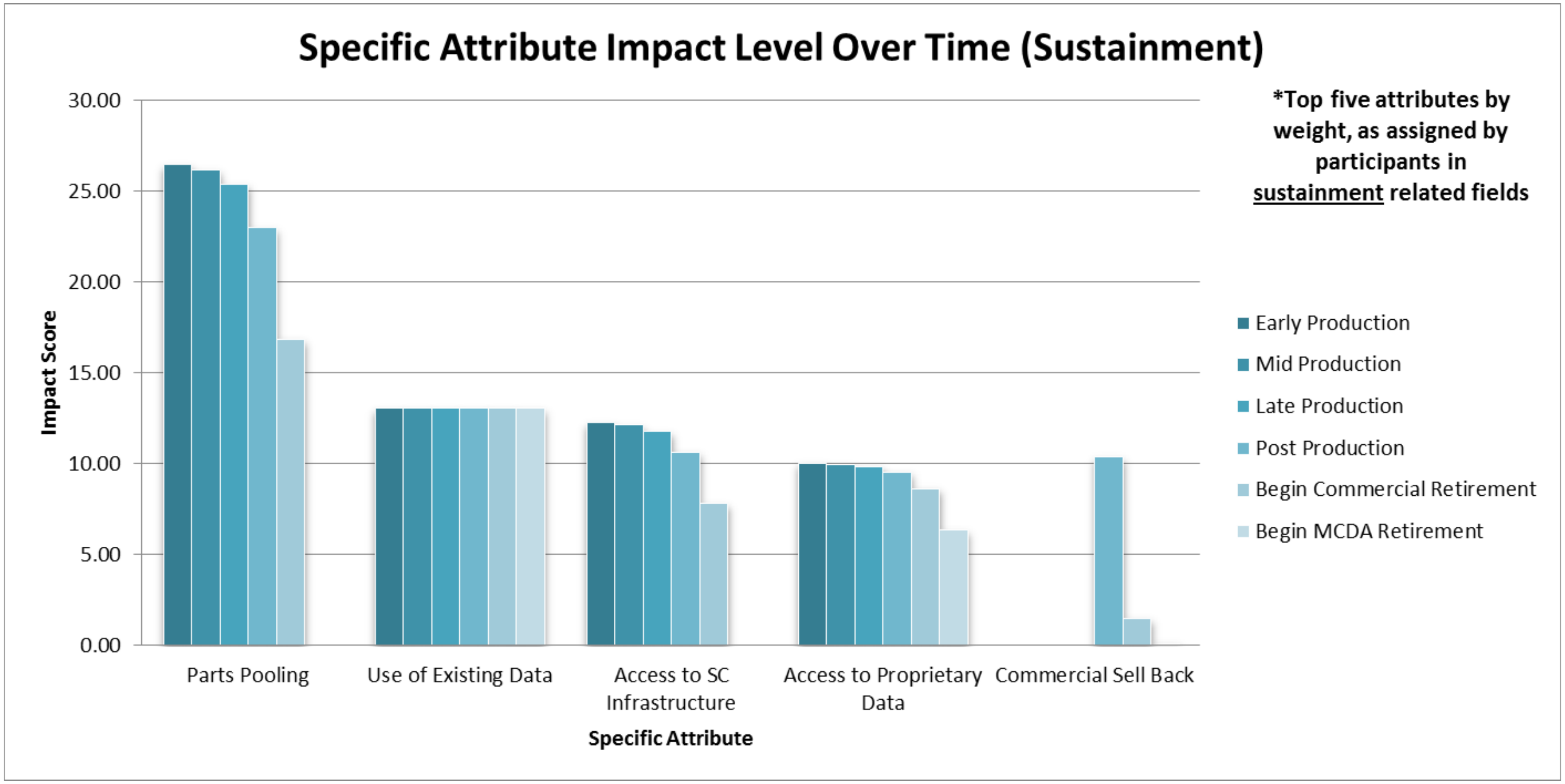
Appendix K. Decision Support Tool Output



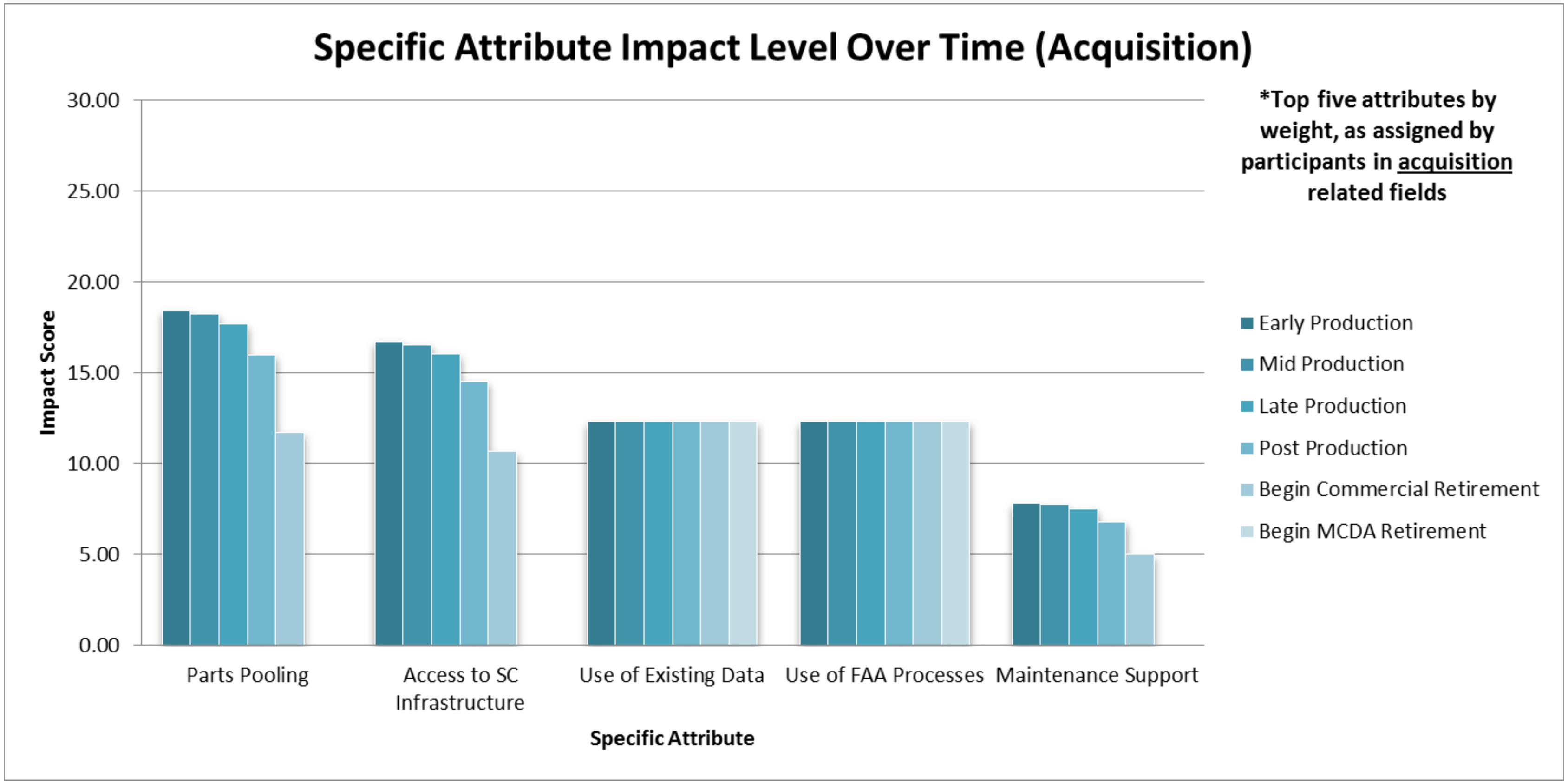
Appendix L. Attribute Comparison



Appendix M. Attribute Comparison (Sustainment)



Appendix N. Attribute Comparison (Acquisition)



Appendix O: Research Request Memo

DEPARTMENT OF THE AIR FORCE
AIR FORCE MATERIEL COMMAND (AFMC)

07 OCT 2011

MEMORANDUM FOR ASC/WKL, OC-ALC/GKA, AMC/A4M, AMC/A5Q

FROM: HQ AFMC/A4D
4375 CHIDLAW RD
WPAFB, OH 45433

SUBJECT: Request for Commercial Derivative Aircraft Research Project Input

1. As the designated representative for the HQ AFMC/A4 for studies, I am requesting your support with one of our sponsored research projects to identify ways to reduce the costs of new aircraft acquisition and sustainment. In particular, this project seeks to quantify the benefits and costs associated with Air Force use of FAA certified commercial derivative aircraft (CDA) and to develop a tool to assist with future decisions. This research can only be successful through your active participation and we will be pleased to share all of our results with you.

2. We ask that you identify five individuals from your organization to review a set of decision criteria regarding Air Force use of CDA and FAA certification processes. Individuals selected to participate must be military or DoD civilian personnel and should be familiar with Air Force acquisitions of commercial derivative aircraft (i.e. C-27J, KC-46A, etc.). After reviewing a few paragraphs of material, participants will be asked to answer five questions based on their knowledge and experience. Subsequent survey rounds (a maximum of four) may be required to clarify responses and/or reach agreement amongst participants. Estimated time to complete the initial review and answer questions should not exceed 30 minutes. Participant anonymity will be preserved in all project reports.

3. The research project point of contact is Capt Mike Low – Phone 520-481-9246; E-mail – Michael.low@afit.edu.

BRIAN C. BURKS
Chief, Depot Operations Division
Directorate of Logistics
Wright-Patterson AFB, OH

Attachment:

1. Questionnaire with Instructions

Appendix P. Human Experimentation Requirements Exemption Letter

DEPARTMENT OF THE AIR FORCE
AIR FORCE INSTITUTE OF TECHNOLOGY
WRIGHT-PATTERSON AIR FORCE BASE OHIO

29 September 2011

MEMORANDUM FOR DR. ALAN JOHNSON

FROM: William A. Cunningham, Ph.D.
AFIT IRB Research Reviewer
2950 Hobson Way
Wright-Patterson AFB, OH 45433-7765

SUBJECT: Approval for exemption request from human experimentation requirements (32 CFR 219, DoDD 3216.2 and AFI 40-402) for Delphi Study of Commercial Derivative Aircraft and Certification Criteria.

1. Your request was based on the Code of Federal Regulations, title 32, part 219, section 101, paragraph (b) (2) Research activities that involve the use of educational tests (cognitive, diagnostic, aptitude, achievement), survey procedures, interview procedures, or observation of public behavior unless: (i) Information obtained is recorded in such a manner that human subjects can be identified, directly or through identifiers linked to the subjects; and (ii) Any disclosure of the human subjects' responses outside the research could reasonably place the subjects at risk of criminal or civil liability or be damaging to the subjects' financial standing, employability, or reputation.

2. Your study qualifies for this exemption because you are not collecting sensitive data, which could reasonably damage the subjects' financial standing, employability, or reputation. Further, the demographic data you are collecting cannot realistically be expected to map a given response to a specific subject.

3. This determination pertains only to the Federal, Department of Defense, and Air Force regulations that govern the use of human subjects in research. Further, if a subject's future response reasonably places them at risk of criminal or civil liability or is damaging to their financial standing, employability, or reputation, you are required to file an adverse event report with this office immediately.

WILLIAM A. CUNNINGHAM, PH.D.
AFIT Research Reviewer

Appendix Q. Delphi Study Participant Pool

<u>Aeronautical Systems Center (AFMC)</u>

<u>HQ AMC/A4M Logistics (Maintenance)</u>

<u>HQ AMC/A5Q Strategic Plans, Requirements, and Programs (Requirements)</u>

<u>Oklahoma City Air Logistics Center (AFMC)</u>

<u>76th Maintenance Wing (AFMC)</u>

Appendix R: Quad Chart

Impact of Decision Criteria on Federal Aviation Administration Certification of Military Commercial Derivative Aircraft

Capt Mike Low
Advisor: Dr. Alan Johnson
Department of Operational Sciences (ENS)
Air Force Institute of Technology

INTRODUCTION

The decision regarding whether to maintain Federal Aviation Administration certification of military commercial derivative aircraft (MCDA) can be extremely difficult due to the subjective nature of some of the associated costs and benefits. The purpose of this research is to help decision makers understand the level of impact those costs and benefits have on their decision and how that impact may change over the lifecycle of the MCDA fleet. Data regarding the various criteria involved in such decisions were collected from subject matter experts using the Delphi technique. This data were then incorporated into a decision support tool that uses the principles of multi-attribute decision making. The tool helps to illustrate the relative importance of each of the decision criteria based upon specific points in a typical MCDA fleet lifecycle.

RESEARCH QUESTIONS

- *What are the decision criteria USAF leaders should consider when determining whether or not to maintain FAA certification of MCDA?*
- *How do the costs and benefits associated with maintaining FAA certification of MCDA change over time?*
- *If the choice is made to maintain FAA certification of MCDA, how long should it be maintained?*

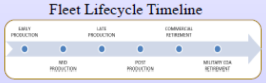
DECISION CRITERIA

1. Participation in the commercial parts (spares) pool
2. Access to established commercial maintenance support and infrastructure
3. Access to an established commercial supply chain
4. Use of existing manuals, repair/failure data, and technical data
5. Use of existing FAA approved processes (Service Bulletin and Airworthiness Directive processes, repair processes, etc.)
6. Improved control and tracking of aircraft configuration data
7. Ability to participate in cross-servicing with European Aviation Safety Agency (EASA) and FAA fleets
8. Ability to sell demilitarized MCDA back to commercial market
9. Reduced need to acquire proprietary OEM design data or flight test data
10. Improved safety due to increased FAA oversight

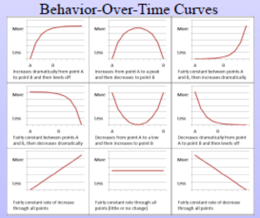
ASSUMPTIONS

- Decision to utilize MCDA has already been made by USAF
- Most costs associated with FAA certification are sunk or fixed costs
- Attribute behavior can be described using exponential and linear curves
- Military benefits associated with maintaining FAA certification are allowed by commercial industry (i.e. access to commercial parts pool)

Fleet Lifecycle Timeline

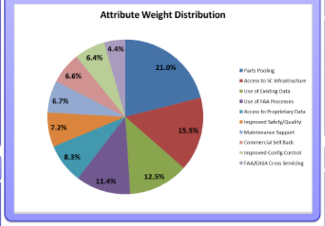


Behavior-Over-Time Curves



Lifecycle Impact Scores

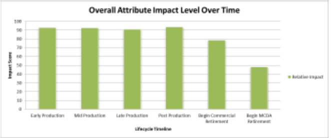
Lifecycle Stage	Early Production	Mid Production	Late Production	Post Production	Begin Commercial Retirement	Begin MCDA Retirement
Impact Score	92.97	92.45	91.07	93.54	77.18	47.20

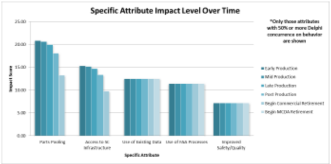


Sponsor
AFMC/A4D
Mr. Mike Dawson

MULTI-ATTRIBUTE DECISION SUPPORT TOOL

		MCDA Fleet Life Cycle Stages											
		Early Production		Mid Production		Late Production		Post Production		Begin Commercial Retirement		Begin MCDA Retirement	
FAA Certification Decision Criteria (Attributes)	Attribute Weight	Impact Level	Impact Score	Impact Level	Impact Score	Impact Level	Impact Score	Impact Level	Impact Score	Impact Level	Impact Score	Impact Level	Impact Score
Parts Pooling	21.0	0.99	20.79	0.98	20.58	0.95	19.95	0.86	18.06	0.63	13.23	0	0.00
Access to SC Infrastructure	15.5	0.99	15.35	0.98	15.19	0.95	14.73	0.86	13.33	0.63	9.77	0	0.00
Use of Existing Data	12.5	1	12.50	1	12.50	1	12.50	1	12.50	1	12.50	1	12.50
Use of FAA Processes	11.4	1	11.40	1	11.40	1	11.40	1	11.40	1	11.40	1	11.40
Access to Proprietary Data	8.3	1	8.30	0.99	8.22	0.98	8.13	0.95	7.89	0.86	7.14	0.63	5.23
Improved Safety/Quality	7.2	1	7.20	1	7.20	1	7.20	1	7.20	1	7.20	1	7.20
Maintenance Support	6.7	0.99	6.63	0.98	6.57	0.95	6.37	0.86	5.76	0.63	4.22	0	0.00
Commercial Sell Back	6.6	0	0.00	0	0.00	0	0.00	1	6.60	0.37	2.44	0.14	0.92
Improved Config Control	6.4	1	6.40	1	6.40	1	6.40	1	6.40	1	6.40	1	6.40
FAA/EASA Cross Servicing	4.4	1	4.40	1	4.40	1	4.40	1	4.40	1	4.40	1	4.40
Totals	100		92.97		92.45		91.07		93.54		78.70		48.05





RESULTS

- Parts pool/supply chain access and use of data represent half of total impact
- Parts pool and supply chain access benefits diminish rapidly at commercial fleet retirement, but use of data benefit remains steady over timeline
- Remaining attribute behavior is mixed, but most remain steady over time
- While overall attribute impact diminishes as commercial fleet retires, much of the benefit to maintaining FAA certification remains to end of lifecycle

FUTURE RESEARCH

- Accurately identify costs associated with upgrading military systems to allow unlimited access to commercial supply chain parts and infrastructure
- Expand topic to DoD level and include all branches in the Delphi study
- Consider streamlining of military and FAA certification processes
- Consider FAA certification as a step toward international certification

DEPARTMENT OF OPERATIONAL SCIENCES

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Vita

Captain Mike Low enlisted in the U.S. Air Force in 1989 as an Avionics Guidance and Control Systems Apprentice. Attending Wayland Baptist University while on active duty, he earned his baccalaureate degree in operational education in 2004. He gained an officer commission through the Air Force Officer Training School in 2004, and completed his master of aeronautical science degree from Embry-Riddle Aeronautical University in 2008.

His previous assignments include Yokota AB, Japan; Rhein-Main AB, Germany; Andersen AFB, Guam; Hickam AFB, Hawaii; Davis-Monthan AFB, Arizona; and Langley AFB, Virginia prior to his assignment to Wright-Patterson AFB, Ohio as an AFIT student. While at AFIT, he helped prepare and present “An Application of Bloom’s Taxonomy in a Graduate Organization Behavior Course: A Multi-media Portfolio Project” for the Ohio Teaching & Learning Conference in October 2011. Also while at AFIT, Capt Low was a member of the Sigma Iota Epsilon professional management fraternity.

He has performed as an on-equipment and off-equipment avionics technician, flight line expeditor, quality assurance inspector, Assistant Maintenance Operations Officer, Aircraft Maintenance Unit Officer-in-Charge, and Headquarters Air Combat Command’s Assistant Chief of Flight Safety for Aircraft Maintenance and Munitions. He has experience on A-10A/C, C-130E/H, C-141B, C-17A, C-5A/B, B-747 and DC-8 aircraft.

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